DOCUMENT RESUME

ED 217 204 CE 032 788

AUTHOR	Firenze, Robert J.; Walters, James B.
TITLE	Safety and Health for Industrial/Vocational Education; for Supervisors and Instructors.
INSTITUTION	National Inst. for Occupational Safety and Health (DHHS/PHS), Cincinnati, OH. Div. of Training and Manpower Development.; Occupational Safety and Health Administration, Washington, D.C.
PUB DATE	Jul 81
NOTE	583p.
EDRS PRICE	MF03/PC24 Plus Postage.
DESCRIPTORS	Accident Prevention; Administrator Guides; Behavioral Objectives; Educational Facilities; Electricity; Equipment Maintenance; Equipment Utilization; Facility Guidelines; Fire Protection; Guidelines; *Health; Industrial Arts; Inservice Teacher Education; Lighting; Machine Tools; Occupational Safety and Health; Planning; *Program Administration; *Program Development; *Safety; Safety Education; Safety Equipment; School Safety; School Shops; Secondary Education; Teaching Guides; *Trade and Industrial Education; *Vocational Education; Welding
IDENTIFIERS	Hazardous Materials; Hazards

ABSTRACT

This course is designed to enable industrial/vocational education supervisors and instructors to establish and administer effective safety and health programs in their schools. Although the course is intended as complete training to be given over a 3-day period, it may be divided into individual units for presentation over longer periods of time. Covered in the 17 units of the course are the following topics: the impact of accidents on industrial/vocational education shop programs, organization for safety and health programs, essential processes in hazard control, shop operations and hazard analysis, safety committees, accident investigation techniques, principles of good shop planning, safe working surfaces, maintaining the industrial/vocational school shop, illumination and color for safety, fire protection, health hazards, personal protective equipment, machine guarding, safety and health considerations in welding and cutting operations, and electrical safety. Each unit contains a description of methods to be used in conducting the lesson, its purpose and objectives, special terms, instructor materials, and trainee materials. (MN).

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ED217204

SAFETY AND HEALTH FOR INDUSTRIAL/VOCATIONAL EDUCATION

FOR SUPERVISORS AND INSTRUCTORS

Developed by
Division of Training and Manpower Development
Curriculum Development Branch

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CE 032 788

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control

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Cincinnati, Ohio

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
Washington, DC

July 1981

U.S. DEPARTMENT OF EDUCATION
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REMARKS TO PROGRAM ADMINISTRATORS

This course has been prepared so that industrial/vocational education supervisors and instructors can establish and administer effective safety and health programs in their schools.

The primary purposes of the course are:

1. to acquaint supervisors and instructors at various levels with the characteristics of effective safety and health programs
2. to demonstrate the relationships between hazards encountered in the industrial/vocational shop and those existing in industry
3. to provide information on safety and health problem identification and evaluation, inspections, accident investigations, and the selection and use of effective hazard controls
4. to teach the participant to differentiate important hazards from those with lesser destructive potential.

Although this course is designed as a complete training program to be given over a three-day period, it may be divided into individual units for presentation over longer periods of time.

Before any instruction takes place, the participants must be well versed in the purposes, content and strategies of this course. As the program administrator, you will be responsible for ensuring that your instructors understand the purpose and the specific objectives of each program unit. You should feel free, by making additions and deletions, to tailor the content to fit a particular situation. Wherever possible, the administrator is urged to replace or supplement visual aids with ones taken from the industrial/vocational shop settings of the program participants. In this way, the presentation will gain in effectiveness and immediacy.

PILOT EVALUATION AND TECHNICAL REVIEW

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Judith Gero	Safety Instructor	Maine
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Herbert Carlson	Vocational Instructor	Florida
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Rudolph Daniels	Vocational Instructor	Florida
Donald Gilliamsen	Safety Supervisor	Florida
Roy Hellman	Industrial Vocational Coordinator	Florida
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Donald Reinhofer	Industrial Arts Instructor	Florida
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UNIT 1

IMPACT OF ACCIDENTS ON INDUSTRIAL/VOCATIONAL EDUCATION SHOP PROGRAMS

METHODS

Lecture and Demonstration

LENGTH: 60 Minutes

PURPOSE

To discuss the effects of accidents and hazards on operations within the industrial/vocational education shop and to examine how students are involved in accident situations.

OBJECTIVES

To introduce the participant to:

1. The impact of accidents on school shop operations
2. The origin and cause of safety and health hazards in the shop
3. The student as part of an operator/machine system.

SPECIAL TERMS

1. Accident/Injury
2. Safety Hazard
3. Health Hazard
4. Operator/Machine System
5. Human, Situational and Environmental Factors

INSTRUCTOR MATERIALS

Lesson Plan
35 mm Slides and Projector
Chalk Board/Chalk

TRAINEE MATERIALS

Participant Outlines and Supplementary Materials

UNIT 1

IMPACT OF ACCIDENTS ON INDUSTRIAL/VOCATIONAL EDUCATION SHOP PROGRAMS

IMPACT OF ACCIDENTS IN INDUSTRY

Each year accidents continue to take their toll on workers in all industries. Recent figures compiled by the National Safety Council indicate that over 2,300,000 workers are disabled and over 13,000 are killed annually as a result of accidents occurring in the workplace.[1] These statistics do not include the injuries and deaths sustained in school industrial/vocational education shops.

IMPACT OF ACCIDENTS IN INDUSTRIAL/VOCATIONAL EDUCATION

From figures distributed by the National Safety Council, we can estimate that, during one year, industrial/vocational education shops were the location of more than 22,500 accidents to boys and 1,500 accidents to girls.[2] These figures are only for those accidents which were reported and which caused property damage or loss of at least one half-day of school. Actual figures would be much higher for three reasons:

1. The total number of students participating in industrial/vocational education programs throughout the nation is increasing.
2. Many accidents are not reported.
3. Many accidents do not cause property damage or result in the loss of at least one half-day of school.

ACCIDENT EFFECTS

Accidents are harmful not only when measured in human terms, that is, the injuries and illnesses to students, instructors and others in the school system, but also when measured in terms of their impact on the overall school shop program. Along with human losses, accidents which occur in the shop setting generally include one or more of the following results:

1. damage to or loss of equipment
2. damage to or loss of materials
3. temporary or permanent loss of the use of shop facilities
4. cost of medical treatment

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5. administrative costs
6. liability.

ACCIDENT REDUCTION IN THE SCHOOL SHOP

Supervisors of industrial/vocational education programs must understand the importance of a systematic approach to locating, evaluating and controlling those factors in the shop situation and environment which are responsible for accidents and their effects. Developing an effective program to reduce accidents and adverse health conditions requires the efforts of many people directly and indirectly associated with instructional activities.

ACCIDENT REDUCTION —A TEAM APPROACH

Administrator/Supervisor

Principal and Assistants

Department Heads

To be effective, a safety and health program requires the active leadership and support of those at both the administrative and instructional levels. The industrial/vocational school administrator or supervisor, for example, plays a significant role from the standpoint of direction and overall policy setting. The school principal and assistants, through their support and program assistance, are also important links in the total effort. So too are the various industrial/vocational education department heads, who are in prime positions to provide overall guidance and individual instructor support.

Instructor

Purchasing Agents

Student Shop Foremen

Safety and Health Committee

Maintenance Personnel

Perhaps the key person, from the standpoint of his day-to-day contact with the shop and students, is the instructor. Through his active leadership and participation, this person makes the program happen. Other key individuals and groups are those responsible for purchasing materials and equipment for the school shop, those assigned roles as student shop foremen, members of safety and health committees and those charged with maintaining shop facilities.

Later in this section, the actual support roles of team members will be examined further. But before we can discuss ways that individuals and groups can reduce or eliminate accidents within the total health and safety program, it is necessary to explore in depth the nature and causes of accidents.

DEFINITION OF ACCIDENT

Let us begin by enlarging and refining our definition of accident. Thus far "accident" has referred to a situation responsible for the undesired events of injuries, fatalities or any other losses. For the remainder of this course, the term "accident" will be defined as:

> any unexpected event which interrupts the normal shop educational process, caused by human, situational or environmental factors or a combination of these. It may or may not result in death, injury or property damage but has the potential to do so.[3]

Three important points contained in our definition need further explanation.

Accidents Do Not Have to Result in Injuries

The first is that an accident does not have to result in damage, injury or death. For instance, a student slips and falls on an oil spot while walking across the shop floor. The fall does not injure the student or cause any damage, but it is still classified as an accident because it interrupts the educational process and carries with it the potential for injury and damage.

Accidents Are Unusual Events

The second point is that accidents, by their very nature, are unusual, unexpected events. Yet the fact that accidents occur infrequently is not as important as the recognition that the potential for accidents is always present. An oil spot on a shop floor, for example, may remain there for many days without anyone slipping on it or taking particular notice of it, but that does not reduce the oil spot's potential to cause injury or damage. Unless instructors and students are aware of and fully alert to the ever present possibility of accidents, unless they act to discover and eliminate potential causes, sooner or later these causes probably will produce situations in the industrial/vocational education shop where both instructors and students will witness damage, injuries or death.

Accidents Are Caused

The third point our definition makes is that accidents do not occur without reason; they are *caused.* Common causes of shop accidents are:

1. improper use of tools, machines, etc.
2. failure to use protective equipment
3. protective and safety equipment that has been rendered inoperative
4. failure to follow correct procedures
5. faulty equipment and tools
6. condition of walking and working surfaces
7. improper maintenance of equipment
8. unguarded or inadequately guarded machinery.

Accidents Caused by Human, Situational and Environmental Factors

In each accident situation, the cause can be directly or indirectly attributed to either the instructor or student (human factors), operations, tools, equipment and materials (situational factors), and conditions such as noise, vibration, poor illumination, etc. (environmental factors).

Before any attempt is made to improve the industrial/vocational education shop setting and its instructional methods, operations and conditions, it is imperative that the causes of accidents be fully understood. Let us begin by exploring the human factor and then proceed to the situational and environmental factors.

CAUSE FACTOR ONE —HUMAN FACTOR

Acts of Commission and Omission

By the human factor, we mean the person who, by his commission (what he does) or by his omission (what he fails to do), causes an accident. A student or instructor may cause an accident by his commission, for example, when he sharpens a wood gouge on a grinder without resting the tool on the grinder's rest. He may cause an accident by an act of omission when he fails to wipe an oil spot from the floor. Each of these actions is generally described as an unsafe act, that is, a human action which departs from hazard control procedures or practices or causes unnecessary exposure of a person to a hazard or hazards. The basic types of unsafe acts are:

Unsafe Act

Types of Unsafe Acts

1. using equipment without authority
2. operating equipment at an unsafe speed or in any other improper way
3. removing safety devices or rendering them inoperative
4. using defective tools.

When Human Error May Not Be an Unsafe Act

Whenever a student or instructor is directly involved in an accident, it seems that his actions are automatically tagged "unsafe." While a great many accidents are the result of someone doing something which he is not supposed to do, knowing very well that he is not supposed to do it (unsafe act), there are other situations where the student or instructor becomes the target for criticism when, although he was directly involved in the accident, other factors forced him into this involvement. The following example illustrates this point.

Suppose a student, after receiving sufficient instruction on the use of a newly installed table saw guard, is required to make a particular cut which cannot be made with the guard in proper position. In this case the required task causes the student to remove the guard temporarily so that the cut can be made. While removing the guard, his hand slips off the wrench and is cut on the saw blade. Obviously the student was instrumental in the accident situation, and consequently many people would view what he did as an unsafe act. A closer analysis of the situation reveals, however, that the blame cannot be placed solely on the shoulders of the student.

In this instance a failure in the shop management system contributed to the accident. First of all, those in charge of purchasing the particular guard should have done so with a better knowledge of its capabilities, limitations and compatibility with educational task requirements. Secondly, the instructor should have made certain that the student understood the necessity for using the guard, as well as how to maintain and remove it when necessary. Most importantly, the instructor should have provided a contingency plan for protection if and when the saw would have to be used without adequate guarding.

Differentiating between student error and supervisory error is a very important first step in preventing future accidents in the school shop and will determine whether or not the actions taken by school supervisors will reduce accident potential or create additional hazards.

Reducing Human Error Through:

Following are five key factors which can reduce human error in the school shop.

Knowledge

First, instructors and students must know the correct methods and procedures to accomplish given tasks.

Ability

Second, students should demonstrate a skill proficiency before using a particular piece of equipment. Many accidents are the result of a person's inability to use equipment, tools and safety devices correctly.

Physical Fitness

Third, a person's physical characteristics and fitness must be taken into consideration as it affects his/her operations within the school shop. For example, poor eyesight or a problem with depth perception is a factor which can cause a student to make a faulty judgment. The temporary loss of the use of a hand or fingers because of an injury may interfere with the manual dexterity required to do the job safely.

Personal Regard for Safe Working Practices

Fourth, instructors and students should maintain a high and continuous regard for their own and their classmates' safety and health. If they are constantly aware and always alert to potentially dangerous situations, take corrective action and encourage others to do the same, then great progress will be made in making the shop a safe and productive place to live and learn.

Supervision

Fifth, the instructor in charge must provide proper supervision. The instructor must be constantly aware of the level of skill each student has acquired working with every piece of equipment and tool in the shop and adjust the supervision of each student accordingly. Furthermore, when the instructor lets it be known that he will accept nothing less than safe work practices and as safe a shop as possible, he establishes an important principle which shapes his students' attitudes and actions, not only in his shop but in all the shops in which they will work.

CAUSE FACTOR TWO —SITUATIONAL FACTORS

Along with human factors, situational factors are another major cause of accidents in the industrial/vocational education shop. Situational factors are those operations, tools, equipment and/or materials which contribute to accident situations. Examples are:

1. unguarded, poorly maintained and defective equipment
2. ungrounded equipment which can cause shock
3. equipment without adequate warning signals
4. poorly arranged equipment which creates congestion hazards
5. equipment located in positions which can expose more people to a potential hazard than is necessary.

Causes of Situational Problems

Causes of situational problems which can produce accidents in the industrial/vocational education shop are:

Defects in Design

1. defects in design (e.g., a container for use with flammable materials without adequate venting devices and constructed from lightweight metal)

Poor Construction

2. poor, substandard construction (e.g., a ladder built with defective lumber or with a variation in the space of its rungs)

Improper Storage of Hazardous Materials

3. improper storage of hazardous materials (e.g., oxygen and acetylene cylinders stored in an unstable manner and ready to topple over with the slightest impact)

Inadequate Planning, Layout and Design

4. inadequate planning, layout and design (e.g., a welding station located near combustible materials or placed where many students without protection are exposed to the intense light of a welding arc).

CAUSE FACTOR THREE —ENVIRONMENTAL FACTORS

The third factor in accident causation is the environmental one, the way in which the school shop setting directly or indirectly can cause or contribute to accident situations. Environmental factors fall into three broad categories: physical, chemical and biological.

Physical Category

Physical Category. Noise, vibration, fatigue, illumination, heat and cold are examples of factors which have the capacity directly or indirectly to influence or cause accidents. If operations on a machine lathe, for example, produce high noise levels, such noise may interfere with communications in the shop environment. Thus, a student may be unable to warn another student of a hazard in time to avoid an accident.

Chemical Category

Chemical Category. Under this category are toxic fumes, vapors, mists, smokes and dust. In addition to causing illnesses, these elements often impair a student's skill, reactions, judgment or concentration. For example, a student who has been exposed to the narcotic effect of some solvent vapors may experience an alteration of his judgment and move his hand too close to the cutting blade of a milling machine.

Biological Category

Biological Category. This category is seldom experienced by those in school shops but is experienced by many workers in industry. Biological factors are those which are capable of making a person ill from contact with bacteria and microorganisms (e.g., maintenance personnel working around waste systems and sewage facilities or students working with cutting oils without adequate protection).

SOURCES OF SITUATIONAL AND ENVIRONMENTAL HAZARDS

Situational and environmental hazards enter the industrial/vocational education shop from many sources. The primary contributors are:

1. students
2. those responsible for purchasing items for use in the shop
3. those responsible for tool, equipment and machinery placement and for providing adequate machine guards
4. those responsible for maintaining shop equipment, machinery, tools, etc.

Students as Source

Students contribute to situationally and environmentally caused hazards in industrial/vocational education shops by disregarding safety rules and regulations, by making safety devices inoperative, by using equipment and tools incorrectly, by using defective tools rather than taking the time to secure serviceable ones, by failing to use exhaust fans when required and by using toxic substances in unventilated areas.

Purchasing Department as Source

Those responsible for purchasing items for the industrial/vocational education shop are often instrumental in causing situational and environmental hazards. With little consideration given to hazards, those in charge of the purchasing task sometimes acquire

Purchasing Equipment without Guards

Purchasing Hazardous Materials

Failure to Acquire Adequate Information for Use of Hazardous Materials

tools, equipment and machinery without adequate guards and other safety devices, especially if such items can be obtained at a bargain. Sometimes toxic and hazardous materials are purchased, which in many cases could be replaced by materials less toxic and hazardous. Furthermore, purchasing agents sometimes fail to acquire from the vendor and to disseminate to those in charge of the shop program warning and control information.

Design and Machinery Placement as Sources

Those involved in shop layout and design, the placement of equipment and machinery, and the provision of adequate guarding and safety devices or equipment also contribute to hazardous situations in the shop. Examples are:

Improper Placement of Machinery

1. placing equipment and machinery with reciprocating parts where students and instructors can be crushed between the equipment and substantial objects

Improper Placement of Control Switches

2. installing electrical control switches on machinery in such a manner that the operator must be exposed to the hazards of cutting tools, blades, etc., in order to start and stop the equipment

Poor Guard Selection

3. installing guards on equipment and machinery which interfere with work operations

Improper Placement of Work Stations

4. locating work stations with high hazard potential where they expose other students unnecessarily (e.g., placing a welding station in the middle of a floor area instead of locating it in a corner or along a wall where better control over the welding light is possible).

Maintenance as Source

Those responsible for shop maintenance are often the cause of hazards in the industrial/vocational education shop. Examples are:

Improperly Insulated Electrical Wires

1. during the course of their work, leaving exposed electrical wire splices without adequate insulation, increasing the possibility of an electrical shock should a student or instructor come in contact with the wires

Failing to Replace Worn Parts

2. not detecting or replacing worn or damaged machine and equipment parts (e.g., abrasive wheels on power grinders)

Failing to Adjust and Lubricate

3. failing to adjust and lubricate equipment and machinery on a scheduled basis

Failing to Inspect

4. failing to inspect and replace worn hoisting and lifting equipment

Failing to Replace Belts

5. failing to replace worn and frayed belts on equipment

Over-Oiling

6. over-oiling motor bearings, resulting in oil being thrown onto the insulation of electrical wiring and onto the shop floor and perhaps damaging the bearings.

HAZARD DEFINITION

So far, we have discussed examples of accident causes. From this point on, accident causes will be referred to as *hazards*. A workable definition of "hazard" is:

> any existing or potential condition in the workplace which, by itself or by interacting with other variables, can result in the unwanted effects of property damage, illnesses, injuries, deaths and other losses.[4]

This definition carries with it two significant points. First, a condition does not have to exist at the moment to be classified as a hazard. When the total hazard situation is being evaluated, potentially hazardous conditions must be considered. Secondly, hazards may not result from independent failure of workplace components but from one workplace component acting upon or influencing another. For instance, if gasoline or another highly flammable substance comes in contact with sulfuric acid, the reaction created by the two substances produces both toxic fumes and sufficient heat for combustion.

Hazards are generally grouped in two broad categories: those dealing with safety (e.g., injuries) and those dealing with health (e.g., illness). Though a hazard is a hazard no matter what its origin, for ease in communication the broad category "hazard" will be subdivided.

Safety Hazard

A safety hazard usually results in trauma. It evolves from a situation in which students may be injured or killed because of electrical, thermal and mechanical conditions (e.g., faulty electrical wiring on tools and equipment; unguarded gears or blades on equipment; oil spots on the shop floor; rags saturated with flammable substances stored in cardboard boxes; grinders without tool rests, with tool rests improperly adjusted or without flange guards).

Health Hazard

A health hazard is a condition in the shop which has the potential to cause illness. Examples of health hazards are high noise levels, dust, fumes from welding, mists, vapors from solvents, smoke from the foundry and forging operations and solvents causing infection.

Combination Safety and Health Hazard

A single condition, substance or material can be classified as both a safety and health hazard at the same time. For example, benzene vapor can cause lung irritation and perhaps more advanced forms of illness if inhaled over long periods of time. If this substance is used in a closed room without adequate ventilation or comes in contact with an open flame, it may ignite and explode, causing severe injury and death to workers and extensive property damage. In this case, the benzene vapor, normally considered a health hazard, is also a safety hazard.

So far we have discussed the nature and major causes of accidents occurring in industrial/vocational education shops. We have defined accident fully and refined that definition further by labeling as hazards the causes of accidents. We have discussed the individual elements that make up a shop setting; that is, the network of machines, surroundings, operations and human beings that are referred to as the operator/machine system. Our next task is to explore the proper function of each of these elements within the operator/machine system.

ELEMENTS WITHIN THE OPERATOR/MACHINE SYSTEM

1. THE STUDENT

Each student in the industrial/vocational education shop, like workers in industry, performs a job as part of a network referred to as an operator/machine system. In order for the system to move toward its objectives, a student must carry out his role effectively and avoid taking unnecessary risks. To do this, the student must be made aware of the following:

1. the necessary requirements of the task and the steps he will take to accomplish it
2. his own knowledge, skill, and limitations and how they relate to the task
3. what will be gained if he attempts the task and succeeds
4. the unfavorable consequences that will result if his attempt at the task fails
5. what will be lost if he does not attempt to accomplish the task at all.[5]

Basic Functions of Human Component:

In any operator/machine system, the human component fulfills three basic functions: (1) sensing, (2) information processing and (3) controlling.

a. Sensing

As a "sensor," the human serves to monitor or gather information. The student does such things as:

1. feeling excess vibration
2. hearing abnormal engine noises
3. smelling peculiar odors

4. observing that a belt is frayed.

b. Information Processing

As an information processor, the student uses the information collected to make a decision about the relevance or appropriateness of various courses of action.

c. Controlling

The third function flows from the first two in that, once information is collected and processed, the human serves as a controller to keep the situation within acceptable limits or to take the necessary action that will bring the system back into an acceptable (i.e., safe) range.

In analyzing our accident situation and looking at corrective actions aimed at the human, we should do so in light of the three functions discussed above. The questions we should ask, then, are the following:

1. *Sensing:* Did the error occur while the student was gathering information through his senses? Was the student able to perceive the information (e.g., no glare, adequate illumination)?

2. *Processing:* Did the error occur as a result of faulty information processing and decision making?

3. *Controlling:* Did the error occur because the instructor or student took action which was not appropriate? Was an appropriate control option available?

2. TOOLS, MACHINES AND EQUIPMENT

The second element within the operator/machine system involves determining operating conditions which can contribute to hazards. From a safety and health standpoint, questions should be raised about the shape of tools, their size and thickness, the weight of equipment, operator comfort, and the strength required to use or operate tools, equipment and machinery.

3. PHYSICAL SURROUNDINGS

In examining the physical surroundings as part of the operator/machine system, we must give special consideration to those factors that might detract from the comfort, health and safety of the student. Special emphasis should be placed on:

1. the shop layout (whether the student has sufficient room while performing his assigned task)
2. adequate illumination (Poorly lit areas not only increase a student's eyestrain but also may increase his chance of making mistakes and having accidents.)
3. such factors as temperature, humidity, noise, vibration and ventilation of toxic materials.

In our attempt to make the school shop a safe and healthy place to work, the above factors along with others in the same class must be controlled as closely as possible.

4. FELLOW STUDENTS

Although this element within the student/machine system is often only casually mentioned, interpersonal relationships play an important role in operational effectiveness. The task one student performs must be viewed in relation to the tasks performed by other students. Special consideration should be given to determining whether the task requires coordinating information, materials and human efforts.

An industrial/vocational education shop which creates a mood of cooperation allows the students to feel that they "belong" to the group. Such an atmosphere contributes to high morale, raises the quality of the work, minimizes horseplay and is conducive to a more controlled operation.

This unit provides the foundation upon which to build an effective safety and health program. We understand now the nature and causes of accidents, and we see that the school shop is a system where students, instructors, tools, machines and the physical setting interact with each other.

NOTES

1. *Accident Facts*, 1978 ed. (Chicago: National Safety Council, 1978), p. 3.
2. Based on *Accident Facts*, 1978 ed., pp. 90—91.
3. Adapted from Robert J. Firenze, *The Process of Hazard Control* (Dubuque: Kendall/Hunt, 1978), p. 18.
4. Adapted from Firenze, *Process of Hazard Control*, p. 74.
5. See Robert J. Firenze, *Guide to Occupational Safety and Health Management* (Dubuque: Kendall/Hunt, 1973), pp. 34—35.

QUESTIONS AND ANSWERS

1. Name three undesirable effects resulting from an accident situation.

Any three from among the following:

a. human losses

b. damage to or loss of equipment

c. damage to or loss of materials

d. permanent or temporary loss of shop facilities

e. cost of medical treatment

f. administrative costs

g. liability.

2. It has been said that accidents do not have to result in injuries to be classified as accidents. Explain this statement.

Injuries are only one outcome of an accident situation. Damage, equipment loss and so forth are other possible outcomes, but it is entirely possible for an accident to produce no visible or calculable effect at all. The important thing to keep in mind is that, whatever the outcome, one factor or a combination of factors caused the accident. Chances are that an accident that caused damage to a piece of equipment today has the potential to cause serious injury tomorrow.

3. What are the three major groupings into which accident causes are placed?

Human, situational and environmental.

4. Give three examples of unsafe acts, commonly responsible for accidents in the industrial/vocational education shop.

Any three examples, including the following:

a. using equipment without authority

b. operating equipment at an unsafe speed or in any other improper way

c. removing or rendering inoperative a safety device

d. using defective tools.

5. What is the difference between a safety hazard and a health hazard?

A safety hazard is a condition resulting in trauma or injury; a health hazard results in illness.

6. What are the elements in the operator/machine system?

a. the student

b. tools, machines and equipment

c. physical surroundings

d. fellow students.

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UNIT 2

ORGANIZATION FOR SAFETY AND HEALTH PROGRAMS

METHODS	Lecture, Class Participation	LENGTH: 45 Minutes
PURPOSE	To discuss the essential elements in organizing an effective safety and health program for industrial/vocational education shops.	
OBJECTIVES	To familiarize the participant with: 1. The necessity for administrative support 2. The necessity for well defined objectives and a policy to guide the program's direction 3. The role of responsibility and authority at all levels of the school organization.	
SPECIAL TERMS	1. Responsibility 2. Authority	
INSTRUCTOR MATERIALS	Lesson Plan Overhead Transparencies, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials	

UNIT 2

ORGANIZATION FOR SAFETY AND HEALTH PROGRAMS

PURPOSE OF ORGANIZATION

To Control Accidents

To Protect Students

To Increase Effectiveness

The purpose of a safety and health program organization is to help school administrators develop and operate a program that will prevent and control accidents involving the three factors discussed in Unit 1: human, situational and environmental.[1] Such a program will protect students and increase the effectiveness of instructional methods and shop operations.

To Provide a Means for Group Participation

The elimination or reduction of accidents in the school shop setting should be of primary importance to everyone in the school. A formal safety and health program will provide a means for administrators, department heads, instructors and students to accomplish safety and health objectives.

A safety and health organization which has specific functions, broad representation and administrative support can help to create a more enjoyable school atmosphere for both instructors and students. Furthermore, the image created by such a program is valuable from a public relations standpoint and furthers the school's reputation while encouraging students to enroll in the industrial/vocational education program.

The figure below illustrates the major components of an industrial/vocational education safety and health program. Each of these elements will be discussed at varying lengths throughout the remainder of this course.

MAJOR COMPONENTS OF A SCHOOL SAFETY AND HEALTH PROGRAM
FOR INDUSTRIAL / VOCATIONAL EDUCATION

SAFETY AND HEALTH PROGRAMS

- Inspection Programs
- Maintenance Programs
- Hazard Analyses
- Housekeeping
- Standards Compliance
- Accident Investigation
- Safety Committees
- Including Hazard Recognition in Instruction & Curricula

- Program Policy
- Program Objectives
- Measuring Program Effectiveness
- Assigning Responsibility & Authority
- Student Orientation, Training & Education
- Supervision
- Program Implementation

ESTABLISHING PROGRAM OBJECTIVES

Critical to the design and organization of a safety and health program is the establishment of objectives and policy to guide the program's development.

The first step, then, is to establish specific objectives to guide the direction of the safety and health program. If the school has a safety and health committee, it would be the logical body to set objectives. Otherwise, the principal will need to appoint a special committee, including instructors, industrial/vocational education department heads and an administration representative. Among the objectives should be:

Gaining and Maintaining Support

1. gaining and maintaining support for the program

Motivating, Educating, Training

2. motivating, educating and training those involved in the program to recognize and correct or report hazards located in the shop area

Engineering Hazard Control into Design

3. engineering hazard control into the design of machines, tools and shop facilities

Providing Inspection and Maintenance

4. providing a program of inspection and maintenance for machinery, equipment, tools and shop facilities

Incorporating Hazard Control

5. incorporating hazard control into school training and educational techniques and methods

Complying with Standards

6. complying with established safety and health standards.[2]

POLICY STATEMENT

Once the objectives have been formulated, the second step is for the principal or director to adopt a formal policy. A policy statement released in printed form over the signature of the highest school administrator should be made available to all school personnel. It should state the purpose behind the safety and health program and require the active participation of all those involved in the program's operation. The policy statement also should reflect:

1. the importance which the school administration places on the health and well-being of its staff and students
2. the emphasis the school places on efficient operations with a minimum of accidents and losses
3. the intention of integrating hazard control into all shop operations
4. the necessity for active leadership, direct participation and enthusiastic support of the entire school organization
5. the intent of the school administration to bring its facilities, operations, machinery, equipment, tools, etc., within compliance with health and safety standards and regulations.

NEED FOR ADEQUATE BUDGET

Adequate funds must be allocated in the school budget for safety and health along with those allocations traditionally associated with the training and educational process. School administrators, with assistance from their instructors and safety and health committees, must define their safety and health program needs and, according to priorities, submit short and long-range (three to five years) budget projections. With such projections in hand, school administrators are able to present their needs to those with fiscal responsibility and stand a better chance of acquiring what they need to make their program function.

RESPONSIBILITY FOR THE SAFETY AND HEALTH PROGRAM

Responsibility for the safety and health program can be established at the following levels:

1. school administrators
2. department heads
3. instructors
4. students
5. student shop foremen
6. purchasing agents
7. maintenance personnel
8. safety committees
9. parents

RESPONSIBILITIES OF SCHOOL ADMINISTRATORS

Before any safety and health program for industrial/vocational education shops gets underway, it is essential that such a program receive the full support and commitment of the top school administrators. The school board, the superintendent, director of industrial/vocational education, principal and others concerned with administration and supervision must accept full responsibility for the safety and health program in its establishment and furnish the drive to get the program started and oversee its operations. Their responsibility is the continuing obligation to carry out an effective safety and health program.

Setting Objectives and Policy

Furthermore, principals or directors must initiate discussions with department heads, instructors and others in the program during pre-planning meetings and periodically throughout the school year. Such discussions may deal with program progress, specific needs and a review of school safety and health procedures and alternatives for handling emergencies in the event an accident occurs.

Supporting Department Heads and Instructors

Specifically, responsibility at this level appears in the form of setting objectives and policy, supporting department heads and instructors in their requests for necessary information, facilities, tools and equipment to conduct an effective shop safety program and establish a safe and healthy educational environment.[3]

Complying with Regulations

In addition, administrators must become cognizant of the fact that they are not maximizing their school's potential efficiency and effectiveness until they bring their operations within compliance with federal and state safety and health regulations, whether or not these regulations are mandatory.

Delegating Authority

In order for any safety and health program to succeed, it is necessary for those in command to delegate the necessary prerogatives to those at various levels of the school. Although responsibility cannot be delegated, authority for hazard control can be.

In Unit 5, we will see how the administration can delegate authority to a Safety and Health Policy Committee, which includes a vice principal, department heads and instructors. The Policy Committee reviews the recommendations it receives from the Shop Safety and Health Committee. In a smaller school the administration will receive directly the recommendations of the Safety and Health Committee, which will act as both the Policy and the Shop Committee.

While authority always must start with those in the highest administrative levels, it eventually must be delegated to other responsible people in order to achieve desired results. If department heads and instructors are to conduct a vigorous and thorough safety and health program, if they are to accept and assert the authority delegated to them when circumstances warrant it, they must be fully confident that they have administrative support.

Asserting Authority

School administrators must understand that, although they can assert authority, they may find resistance unless they have enlisted support from the earliest stages of the program. If the instructors are not aware of the reasons for and the benefits of a thoroughgoing health and safety program, they may resist any changes in their methods of operation and instruction and generally do little to assist the overall program effort.

Insisting on Safety Information

Administrators must insist that safety and health information be included as an integral part of instructional curricula, methods, materials and operations.

Ensuring Effective Fire Protection

In addition, administrators must ensure that effective fire prevention and protection controls exist. For example, they must be aware of the sources of ignition within the school plant, the safety codes and regulations which pertain to the building, how the physical structure of shops and the school facility affects the spread of fire and the methods for detecting and extinguishing a fire should it occur.

Guaranteeing System of Hazard Control

School administrators must guarantee a system where hazard control is considered an important part of equipment purchase and process design, preventive maintenance, shop layout and design and so forth.[4]

School administrators are required to safeguard employees' and students' health by seeing to it that the shop environment is adequately controlled. They must be aware of those shop operations which produce airborne fumes, mists, smokes, vapors, dusts, noise, vibration, etc., that have the capacity to cause impaired health or discomfort among the student population. Administrators must be aware that occupational illnesses may begin in the school shop environment and may eventually take their toll during the years after the student graduates and enters industry.

Requiring Monitoring Program

In order to maintain control over the physical, chemical and biological hazards in the shop environment, school administrators must require a continuous monitoring system. The purpose of the monitoring program is to detect the causes of occupational illness in time to provide early and effective countermeasures. The instructor's daily monitoring has greater weight if it receives administrative backing, student participation and periodic review by the Shop Safety and Health Committee.

Providing a System of Evaluation

Finally, school administrators must provide meaningful criteria to measure the success of the safety and health program and to provide information upon which to base future decisions. They must decide what the program should yield in terms of reduced accidents, injuries, illnesses and their associated losses.

RESPONSIBILITIES OF DEPARTMENT HEADS

The industrial/vocational education department heads are in strategic positions within the school setting. Without their full support, the best designed health and safety program will not be effective. Their leadership and influence ensure that safety and health standards are enforced and upheld in each individual area and that standards and enforcement are uniform throughout the school. Among their many responsibilities are the following:

1. to make certain that materials, equipment and machines slated for distribution to the shops under their jurisdiction are hazard free or that adequate control measures have been provided

2. to make certain that equipment, tools and machinery are being used as designed and are properly maintained
3. to keep abreast of accident and injury trends occurring in their shops and to take proper corrective action to reverse these trends
4. to investigate all accidents occurring within the shops under their supervision
5. to see to it that all hazard control rules, regulations and procedures are enforced in the shops they supervise
6. to require that a Shop Operations Hazard Analysis be conducted for each operation
7. to require that hazard recognition and control information be included in each instructional module and demonstration session
8. to actively participate in and support the Policy and Shop Safety and Health Committee and to follow up on its recommendations.

RESPONSIBILITIES OF INSTRUCTORS

The course instructors in industrial/vocational education carry great influence. With their support school administrators can be assured of an effective safety and health program. Instructors have a moral and professional responsibility to safeguard and educate those who have been placed under their supervision. Thus, instructors are generally responsible for creating a safe and healthy instructional setting and for integrating hazard recognition and control into all aspects of the curriculum. By their careful monitoring they can prevent accidents for which the school carries liability.

For all practical purposes the instructors, like the supervisors or foremen in industry, are the eyes and ears of the shop control system. On a day-to-day basis, instructors must be aware of what is happening in their respective shops, who is doing it, how various tasks are being performed and under what conditions. As the instructors monitor their shops, they must be ready to change part of an operation or the entire operation if they perceive the immediate need for corrective action. The chief safety and health responsibilities of instructors are:

1. to train and educate students in work methods and techniques which are free from hazards

2. to demonstrate an active interest in and comply with school safety and health policies and regulations

3. to actively participate in and support the Policy and Shop Safety and Health Committees

4. to supervise and evaluate student performance with consideration given to safe behavior and work methods

5. to monitor the shop on a daily basis for human, situational and environmental factors capable of causing accidents

6. to correct hazards detected in their monitoring or to report such hazards to the persons who can take corrective action.

7. to investigate all accidents occurring within their shops to determine cause.[5]

RESPONSIBILITIES OF STUDENTS

The students constitute the largest segment of the industrial/vocational school population and are responsible for making the safety and health program succeed. Well-trained and educated students who actively participate in the safety program are probably the greatest deterrent to damage, injuries and death in the industrial/vocational school shop. The most common student responsibilities are:

1. to obey school safety and health rules and regulations and work according to standard shop practices

2. to recognize and report to the instructor hazardous conditions or work practices in the shop

3. to use protective and safety equipment, tools and machinery as they were designed

4. to report all injuries or exposure to toxic material to the instructor as soon as possible.

RESPONSIBILITIES OF STUDENT SHOP FOREMEN

In a well balanced industrial/vocational education safety and health program which includes active participation by the students, a student sometimes serves as the student shop foreman. His job is to inspect, detect and correct. The specific responsibilities of the student shop foreman are:

1. to encourage fellow students to comply with shop safety and health regulations

2. to detect unsafe practices and hazardous machinery, tools, equipment, etc.; to take corrective action when possible;

and to report to the instructor the hazard and the corrective action taken or still required

3. to participate in accident investigations

4. to represent students on the Shop Safety and Health Committee.

RESPONSIBILITIES OF PURCHASING AGENTS

Those responsible for purchasing items for the industrial/vocational education shops, whether they be department heads or specially designated persons, are in a key position to help reduce hazards associated with school shop operations. Among the specific responsibilities of those who purchase items are:

1. to be certain that tools, equipment and machinery are ordered and purchased with adequate consideration for student health and safety and with adequate protective devices

2. to obtain adequate information on the health hazards associated with substances and materials used in shop operations.

RESPONSIBILITIES OF MAINTENANCE PERSONNEL

Those involved with maintaining equipment, machinery and facilities play an important role in reducing accidents in the industrial/vocational education shop. Among the responsibilities of those in maintenance are:

1. to perform construction and installation work in conformance with good engineering practices

2. to comply with acceptable safety and health standards

3. to provide planned preventive maintenance on electrical systems, machinery, equipment, etc., to prevent abnormal deterioration, loss of service, or safety and health hazards

4. to provide for the timely collection and disposal of scrap materials and waste

5. to actively participate in and support the Shop Safety and Health Committee.[6]

RESPONSIBILITIES OF SAFETY COMMITTEES

In Unit 5 of this course, we will examine the role of school safety committees in the overall safety and health program. The Policy and Shop Safety and Health Committees are made up of department heads, maintenance personnel, instructors, students, and administration representatives. Among their responsibilities are:

1. to survey shop facilities for safety and health hazards

2. to advise administration of safety and health hazards found and to offer recommendations for their correction
3. to promote and evaluate shop programs in the recognition of safety and health hazards
4. to critically examine shop safety and health practices and the safety information contained in materials and curricula
5. to evaluate the acceptability of safety devices and personal protective equipment to be purchased for the school shops
6. to conduct accident investigations.

RESPONSIBILITIES OF PARENTS

Although parents are not thought of as part of the organizational framework essential to an effective industrial/vocational education safety and health program, their support and understanding will markedly strengthen such a program. Parents can complement the school effort by placing a strong value on safety and health while their children are at home, involved in recreation or being transported. Parents who have been informed about the aims and importance of safety education willingly will accept the following responsibilities as well:

1. to actively support the enactment and enforcement of school regulations that mandate the acquisition of the most qualified and experienced instructors, as well as the acquisition of equipment and facilities that conform to acceptable safety and health standards for industry
2. to be aware of the potential illness and injury their children are exposed to during their educational and training process
3. to support the instructor and the school administration when penalties must be assigned for violations of safety and health rules.

With the support of each link in the organizational change, an effective industrial/vocational education safety and health program can be established and maintained.

NOTES

1. See *Safety Organization*, U.S. Department of Labor, Bulletin 285 (1967), p. 1.

2. See "Evaluation and Control of Workplace Accident Potential," U.S. Department of Health, Education and Welfare, NIOSH, January 1978, I, V-3. Some material in this unit is developed from this source.

3. See *Safety for Industrial Education and Other Vocational Programs*, Dade County (Fla.) School Board Safety Policies, p. 2.

4. Robert J. Firenze, *Guide to Occupational Safety and Health Management* (Dubuque: Kendall/Hunt, 1973), p. 75. This is the source for the material in this and the following section.

5. See Firenze, *Guide to Occupational Safety and Health Management*, p. 77.

6. For a more thorough treatment of this topic, see *Maintaining Facilities and Operations*, U.S. Department of Health, Education and Welfare, NIOSH, September 1979, I, 5—7.

QUESTIONS AND ANSWERS

1. Many safety and health programs have floundered because those designing such programs never took the time to state clearly the objectives which the program would accomplish. List at least four objectives common to any good program design.

Any four from among the following:

a. gaining and maintaining support at all levels in the school

b. motivating, education and training students to recognize and correct or report shop hazards

c. engineering hazard control into design

d. providing a program of inspection and maintenance

e. incorporating hazard control into class content and operation

f. complying with established safety and health standards.

2. Policy statements released over the signature of the top school administrator set the tone for the program and establish the safety and health effort as a legitimate program. List four major items to be included in policy statements.

Four from among the following:

a. importance which the school administration places on health and well-being of students

b. emphasis on efficient and effective shop operations with a minimum of accidents and losses

c. the intention of integrating hazard control into all shop operations

d. the necessity for active leadership, participation and support of the entire school organization

e. intention of school administration to comply with health and safety standards and regulations.

……

3. Establishing responsibility for safety and health at various levels in the school organization is critical to the program's success. List each of the nine groups who are responsible and describe one of its responsibilities.

……

a. *School administrators:* any one from among the following:

(1) to set objectives and policy
(2) to support department heads and instructors
(3) to insist on safety and health information as part of instruction
(4) to ensure effective fire protection
(5) to guarantee a system of hazard control
(6) to require a monitoring program
(7) to provide a system of evaluation

b. *Department heads:* any one from among the following:

(1) to make certain materials distributed in the shops are hazard free or that adequate controls have been provided
(2) to make certain that equipment is properly used and maintained
(3) to keep abreast of accident and injury trends and to take corrective action to reverse these trends
(4) to investigate accidents
(5) to see that hazard control rules are enforced
(6) to require a Shop Operations Hazard Analysis for each shop operation
(7) to require that hazard recognition and control information is part of instruction and demonstration
(8) to be part of the Policy and Shop Safety and Health Committees

c. *Instructors:* any one from among the following:

(1) to train students in safe methods
(2) to comply with school safety and health policies
(3) to be part of the Policy and Shop Safety and Health Committees

(4) to include safety performance as a consideration in evaluating students
(5) to monitor the shop
(6) to correct or report hazards
(7) to investigate all accidents

d. *Students:* any one from among the following:

(1) to obey school safety rules and work according to standard shop practices
(2) to recognize and report hazardous conditions and work practices
(3) to properly use protective equipment
(4) to report injuries or exposures

e. *Student shop foremen:* any one from among the following:

(1) to encourage fellow students to comply with safety and health rules
(2) to detect and correct or report unsafe practices
(3) to help investigate accidents
(4) to represent students on the Shop Safety and Health Committee

f. *Purchasing agents:* any one from among the following:

(1) to purchase safe tools and equipment and protective devices
(2) to obtain information about health hazards associated with substances and materials used in the shop

g. *Maintenance personnel:* any one from among the following:

(1) to comply with good engineering practices in construction and installation
(2) to comply with acceptable safety and health standards
(3) to provide planned preventive maintenance
(4) to provide for timely collection and disposal of scrap and waste
(5) to be part of the Shop Safety and Health Committee

h. *Policy and Shop Safety and Health Committee:* any one from among the following:

(1) to survey shop facilities for safety and health hazards

(2) to make recommendations to the administration
(3) to promote programs in hazard recognition
(4) to examine shop safety practices and information contained in shop materials and curricula
(5) to evaluate personal protective equipment
(6) to conduct accident investigations

i. *Parents:* any one from among the following:

(1) to support enactment and enforcement of school safety regulations
(2) to be aware of potential illness and injury
(3) to support administration and instructors when penalties are assigned for violation of safety rules.

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U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, *Maintaining Facilities and Operations,* September 1979.

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UNIT 3

ESSENTIAL PROCESSES IN HAZARD CONTROL

METHODS	Lecture and Demonstration	LENGTH: 45 Minutes
PURPOSE	To explain the process of locating, assessing and eliminating—or at least controlling—hazards in the school industrial/vocational education shop.	
OBJECTIVES	To introduce the participant to: 1. The method for locating and evaluating hazards 2. Decision making in hazard control 3. The installation of preventive and corrective measures 4. The role of safety and health inspections 5. Safety and health program evaluations.	
SPECIAL TERMS	1. Shop Operations Hazard Analysis 2. Hazard Consequence Category	
INSTRUCTOR MATERIALS	Lesson Plan Overhead Transparencies, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials	

UNIT 3

ESSENTIAL PROCESSES IN HAZARD CONTROL

ESSENTIAL PROCESSES IN HAZARD CONTROL

This unit will examine the elements of the hazard control process, with emphasis placed on the interplay between these elements. In any good program designed to reduce or eliminate hazards, five essential processes must be present. They are:

1. hazard identification and evaluation
2. administrative decision making
2. establishing corrective and preventive measures
4. safety and health inspections
5. evaluation of program effectiveness.

PROCESS ONE: HAZARD IDENTIFICATION AND EVALUATION

The first process in a comprehensive hazard control program is to identify and evaluate hazards located in the workplace. These hazards are associated with machinery, equipment, tools, operations and the physical plant. The purposes of this first process are to:

1. acquire information about what specific hazards exist
2. rank discovered hazards according to their potential destructive consequences
3. estimate the probability of the hazard resulting in an accident situation.

LOCATING HAZARD INFORMATION

Anyone involved in coordinating the early phases of a safety and health program for a school has many ways to acquire information about hazards associated with their school shops. Here are four ways to acquire hazard information:

Interview Those with Shop Experience

1. Interview those with experience in shop operations.

Examine Shop Surveys and Inspection Reports

2. Examine shop surveys and inspections and facility inspection reports conducted by local, state or federal enforcement organizations, where conditions in the shop can be evaluated against established safety and health standards.

Review Accident Reports

3. Review all school shop related accidents.

Conduct Shop Operations Hazard Analysis

4. Conduct a Shop Operations Hazard Analysis.

FIRST
Interview Those with Shop Experience

The first place to acquire hazard information is from those who are familiar with industrial/vocational education shops and the hazards associated with them. Information of this type can be obtained from:

Other School Safety and Health Personnel

1. safety and health coordinators at other schools which have an effective safety and health program

Insurance Companies

2. insurance company loss control representatives or, for self-insured schools, their corporation counsels who are familiar with those hazards which cause damage, injuries and fatalities in industrial/vocational education programs

Maintenance Personnel

3. school maintenance personnel who are familiar with shop facilities and contents

Manufacturers

4. manufacturers of equipment, tools and machinery used in the shops

Suppliers of Materials

5. suppliers of materials and substances used in the shop

OSHA

6. the Occupational Safety and Health Administration for hazard information from OSHA inspections of industrial workplaces similar to those in the industrial/vocational education shop

NIOSH

7. the National Institute for Occupational Safety and Health (NIOSH) for safety and health hazard information prepared for industrial work activities and facilities that are similar to those in the industrial/vocational shop.

SECOND
Look for Results of Inspections

Another source for acquiring hazard information is collected data from all school shop facility inspections. Reports from facility inspections conducted by local, state or federal enforcement organizations also should be carefully examined. Specific violations or problem areas will add additional information to the hazard data bank. In addition, it will be helpful to acquire OSHA compliance information, which describes violations in industrial settings that may appear in the school shop setting as well.

THIRD
Examine Accident Reports

Hazard information also can be obtained from accident reports. Information concerning the cause of a particular injury, illness or fatality often will reveal hazards which require control. Close review of accident reports also will identify the individuals and specific operations involved, the shop or section of a shop where the accident occurred, the extent of supervision, and possibly deficiencies in knowledge and skill on the part of the injured.

FOURTH
Conduct Hazard Analysis

Definition of Shop Operations Hazard Analysis

Another avenue available for acquiring meaningful hazard information, as well as a thorough knowledge of the demands of a particular shop task, involves the use of Shop Operations Hazard Analysis (SOHA). This is a procedure used to review job methods and uncover hazards that:

1. may have been overlooked in the layout of the shop or school building and in the design of machinery, equipment and shop operations
2. may have developed after the shop or instructional task had been instituted
3. may exist because original procedures, tasks, etc., were modified.

Values of Shop Operations Hazards Analysis:

Viewing Each Operation as Part of System

The greatest benefit of SOHA is that it forces those conducting the analysis to view each operation performed in the shop as a system. In so doing, they are able to assess each step in the operation while considering the relationship between steps and the interaction between students and equipment, materials, the shop facility and other students. Other benefits of Shop Operations Hazard Analysis include:

Identifying Hazardous Conditions

1. identifying hazardous conditions and potential accidents

Providing Information for Control Measures

2. providing information with which effective control measures can be established

Determining Level of Knowledge and Skill and Physical Requirements

3. determining the level of knowledge and skill as well as the physical requirements that students need to execute specific shop tasks

Discovering and Eliminating Unsafe Procedures

4. discovering and eliminating unsafe procedures, techniques, motions, positions and actions.

Unit 4 will be devoted to the topic of Shop Operations Hazard Analysis and its construction, evaluation and ultimate use as a safety, health and decision-making tool in the school shop.

RANKING HAZARDS ACCORDING TO POTENTIAL DESTRUCTIVE CONSEQUENCES

Criteria Required to Judge Hazards

The second aspect of Process One deals with ranking discovered hazards according to their potential destructive consequences. By judging hazards according to established criteria for hazard evaluation, we are able to specify which hazardous conditions warrant immediate action, which can take secondary priority, and which can be addressed in the future.

Without such a system, there can be no consistent guide for corrective action. Even worse, if time is not taken to rank hazards on a "worst first" basis, efforts and resources could be directed toward problems of lower consequence while those with greater destructive potential are overlooked. The following scheme is suggested for hazard evaluation:

Hazard Evaluation Scheme	HAZARD CONSEQUENCE CATEGORY	EXPLANATION
Catastrophic Hazard	I. *Catastrophic Hazard*	The hazard is capable of causing death, possible multiple deaths, widespread occupational illnesses and loss of shop facilities.
Critical Hazard	II. *Critical Hazard*	The hazard can result in death, injury, serious illness and property and equipment damage if not corrected as soon as possible.
Marginal Hazard	III. *Marginal Hazard*	The hazard can cause injury, illness and equipment damage, but the injury, illness and equipment damage would not be serious.
Negligible Hazard	IV. *Negligible Hazard*	The hazard will not result in a serious injury or illness. The potential for the hazard causing damage beyond a minor first aid case is extremely remote.[1]

ESTIMATING HAZARD PROBABILITY

Once the hazards uncovered in the shop have been ranked according to their potential destructive consequences, the next step is to estimate the probability of the hazard resulting in an accident situation. Probability estimates should be made on the following qualitative scale.

Probability Estimate Criteria

HAZARD PROBABILITY CATEGORY
(Qualitative Estimate)

A — Probable
B — Reasonably Probable
C — Remote
D — Extremely Remote

When the hazards have been ranked according to both sets of criteria, it is easy to determine where action is mandated. A hazard rated IA, for example, demands corrective action before a hazard with a rating of ID.

Summary of First Process

In summary, the goal of the first process in an effective hazard control program is to acquire information about as many hazards associated with shop operations as possible. Once this is accomplished, the next step is to arrange the hazards on a worst-first basis. Under such a system, efforts can now be directed toward correcting problems with the most serious consequences and the highest probability of occurrence, while leaving other hazards to be corrected at a later date.

PROCESS TWO: ADMINISTRATIVE DECISION MAKING

The second process involves providing school administrators with full and accurate information, including all alternatives at their disposal, so that they can make intelligent, informed decisions concerning hazard control. Such alternatives will include recommendations for student training and education, the need for better instructional methods and procedures, equipment repair or replacement and shop environmental controls. This information must be presented to school administrators in a form that makes clear what actions are required to improve conditions. It is critically important that the person who reports hazard information does so in a way that promotes rather than hinders action.

Three Alternatives for Administrators

Once school administrators receive hazard reports from safety committees, instructors, etc., they normally have three alternatives:

1. They can choose to take no action. **OPTION I — No Action**
2. They can modify the shop workplace, methods, procedures, etc. **OPTION II — Modify**
3. They can redesign the shop workplace or its components. **OPTION III — Redesign**

Breakdown of Options:

OPTION I — No Action

When school administrators choose to take no positive steps to correct hazards uncovered in the industrial/vocational education shop, it usually is because of one of three reasons:

1. Their hands are tied because of staff, scheduling or economic problems, and they cannot take the action which is required.
2. They are presented with alternatives which are not really alternatives at all, receiving only the best and most costly solutions with no intermediate plans to choose from.
3. They are not aware of the need for and the purposes of hazard control as an integral part of the industrial/vocational education process and thus do not consider it to be of much importance.

OPTION II — Modify

When school administrators choose to modify the shop workplaces, instructional methods, etc., they do so with the idea that their programs are generally acceptable but that, with the reported deficiencies corrected, their programs' performance will be improved. Among examples of modification alternatives are:

1. the acquisition of machine guards
2. the acquisition of personal protective equipment
3. the acquisition of ground-fault circuit interrupters to prevent electrical shock
4. a change in instructional technique
5. decreasing the lubricating intervals for machines and equipment
6. isolating hazardous materials and processes
7. replacing hazardous materials and processes with non- or at least less hazardous ones
8. purchasing tools with adequate grounding systems.

OPTION III — Redesign

Although redesign is not a popular alternative, it is sometimes necessary. When redesign is selected, school administrators must keep in mind that they are going to have to deal with certain problems. One problem is that redesign usually involves substantial cash outlay and inconvenience. Let us say that the air quality in a shop is found to be below acceptable standards. The only way to correct this situation is to completely redesign and install the school's general ventilation system. The problems of cost and inconvenience are obvious.

Another problem that should be anticipated is the distinct possibility that the new design may contain hazards of its own. For this reason, whenever redesign is offered as an alternative, those making such a recommendation must establish and execute a plan to detect problems in their early stages and eliminate or reduce them before they present hazardous conditions.

Formats for Decision Making

One way to expedite decision making regarding actions for hazard control is to present findings in such a manner that administrators can clearly understand the nature of the hazards, their location, their importance, the necessary corrective action and the estimated cost.

Form A

Form A (Table 1), Record of Safety and Health Deficiencies in Industrial/Vocational Education School Shops, illustrates one approach for recording and displaying hazard information for decision making.

FORM A

TABLE 1

RECORD OF SAFETY AND OCCUPATIONAL HEALTH DEFICIENCIES IN INDUSTRIAL/VOCATIONAL EDUCATION SHOP

Shop Name Machine Shop

J. Smith, Shop Committee Chairman
Inspector, Title

Deficiency No.	Date Recorded	Description of Hazardous Condition	Specific Location	Identification of Acceptable Standard	Hazard Rating		Corrective Action	Estimated Costs Required for Correction	Date Deficiency Corrected	Resources Used for Correction
					Conseq.	Prob.				
MS – 1	12/11/79	Ungrounded Tools and Equipment	Throughout Shop	OSHA: Subpart S National Electrical Code, Article 250; 4S	1	A	See Form B	$5,000	1/9/80	$4,900

FORM B

TABLE 2

SPECIFICATIONS FOR CORRECTIVE ACTION

Shop Name Machine Shop

Deficiency No.	Date Recorded	Description of Hazardous Condition	Hazard Rating		Issue/ Enforce Regulation	Training and Education	Modify Curriculum	Improve Supervision	Purchase Safety Equipment	Purchase Materials	Purchase Other Equipment	Modify Methods	Date Deficiency Corrected	Resources Used For Correction
			Conseq.	Prob.										
MS – 1	12/11/79	Ungrounded Tools and Equipment	1	A	X	X				X			1/9/80	$4,900

Form B

Form B (Table 2), Specifications for Corrective Action, enables the decision maker to see where action needs to be taken, who may be involved and how costs are incurred.

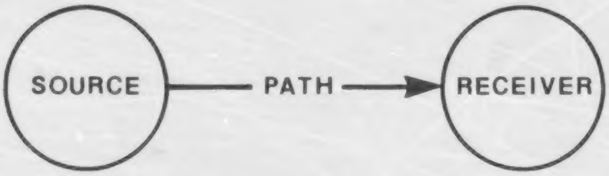
Summary of Process Two

In summary, the purpose behind the second process is to enable school administrators to make informed decisions in order to upgrade their school shop operations and instructional methods while reducing accidents, injuries and other undesirable situations.

PROCESS THREE: INSTITUTING PREVENTIVE AND CORRECTIVE MEASURES

After hazards have been identified and evaluated and information for informed decisions has been provided, the next process involves the actual installation of control measures. Before installation of controls takes place, it is essential that those involved in safety and health activities understand how hazards are controlled. The figure below illustrates the three major areas where we can either eliminate or control hazardous conditions.[2]

Control Model



Control Alternative I: Source

Substitution

The first and perhaps best control alternative is to attack a hazard at its source by substituting a less harmful agent for the one causing the problem. For example, if the safety and health committee finds that a solvent used in the cabinetmaking shop is highly toxic and flammable, the first step is to determine whether the hazardous substance can be exchanged for one which is nontoxic, nonflammable and capable of doing the job. Should the committee not be able to locate a nonhazardous substance which meets these criteria, then it must look for a less toxic, less flammable substance and employ additional safeguards.

Control Alternative 2: Path

Barricading

The second alternative is to control the path of the hazard by erecting a barricade between the hazard and the students. Examples of such engineering controls are:

1. machine guards, which prevent a student's hands from making contact with the table saw blade
2. protective curtains, which prevent student contact with welding lights
3. a local exhaust system, which removes toxic vapors from the breathing zone.

Control Alternative 3: Receiver

The third alternative is to direct control efforts at the receivers, the students. This can be accomplished by:

Remove Student from Hazard

1. removing the student from the hazardous situation by employing automated or remote control options (automatic feeding devices on planers, shapers, etc.)

Personal Protective Equipment

2. providing personal protective equipment when all options have been exhausted and it is determined that the hazard does not lend itself to correction through substitution or engineering redesign.

Protective equipment may be selected for use in the school shop in two instances. The first is when there is no immediately feasible way to control the hazard by more effective means. The second is when it is employed as a temporary measure, while more effective solutions are being installed.

There are, however, major shortcomings associated with the use of personal protective equipment:

1. Nothing has been done to eliminate or reduce the hazard from the shop setting.
2. If the protective equipment (glove, eye shield, etc.) fails for any reason, the student is exposed to the full destructive effects of the hazard.
3. The protective equipment may be cumbersome and interfere with the student's ability to perform a task.

PROCESS FOUR: SAFETY AND HEALTH INSPECTIONS

The fourth process in our hazard control program deals with the inspection or monitoring of activities in order to locate new hazards and assess the effectiveness of existing controls.

Why Inspections?

It is necessary to provide safety and health inspections in industrial/vocational education shops for the following reasons:

1. to provide assurance that hazard controls are working properly
2. to make sure that modifications have not so altered the workplace that hazard controls can no longer function adequately
3. to discover hazards which are new or previously undetected.

The safety and health inspection process will be discussed in detail in Unit 7 of this course.

PROCESS FIVE: PROGRAM EVALUATION

The fifth element in our program deals with evaluating the effectiveness of efforts to improve the overall quality of safety and health within the school. When administrators are dealing with program evaluation, they should answer the following questions:

Questions To Answer:

How Much Is Spent?

1. How much is being spent to locate and control hazards in industrial/vocational education shops?

What Are the Benefits?

2. What benefits are being received?

What Is Impact of Benefits?

3. What impact are the benefits having on improving the overall shop educational process?

Criteria for Measuring Effectiveness

Among the criteria which may assist school administrators in determining the effectiveness of their safety and health program effort are:

1. number of injuries to students compared with shop exposure hours
2. cost of medical care
3. material damage costs
4. facility damage costs
5. equipment and tool damage or replacement costs
6. number of days lost by instructors and students from accidents.

In this unit we have seen how safety and health hazards can be identified, evaluated, and eliminated or controlled. We have described the five essential processes of hazard control, and we can now examine in greater detail the technique known as Shop Operations Hazard Analysis.

NOTES

1. For a more thorough discussion, see Robert J. Firenze, *The Process of Hazard Control* (Dubuque: Kendall/Hunt, 1978), pp. 80–82.

2. Reprinted with permission from Robert J. Firenze, *Guide to Occupational Safety and Health Management* (Dubuque: Kendall/Hunt, 1973), p. 42.

QUESTIONS AND ANSWERS

1. Name the five processes in hazard control.

The five processes are:

a. hazard identification and evaluation

b. administrative decision making

c. establishing corrective and preventive measures

d. safety and health inspections

e. evaluation of program effectiveness.

2. Name two ways of locating health hazards.

Any two from among the following:

a. Interview those with experience in shop operations.

b. Examine shop inspection reports.

c. Examine shop accident reports.

d. Conduct a Shop Operations Hazard Analysis

3. Why must hazards be judged on the basis of their consequences and probability of their occurrence?

Without such a system, there can be no consistent guide for corrective action. Even worse, if time is not taken to rank hazards on a "worst first" basis, our efforts and resources might be directed toward problems of lower consequence while those with greater destructive potential are overlooked.

4. What are the four categories of hazard consequence, and what does each mean?

I. Catastrophic—possible multiple deaths, widespread occupational illnesses, loss of shop facilities

II. Critical—death, injury, serious illness and equipment damage

III. Marginal—injury, illness or equipment damage would not be serious

IV. Negligible—little potential for damage beyond that requiring minor first aid.

5. What are the three areas where a hazardous condition can be controlled?

a. at its source

b. along its path

c. at the receiver.

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UNIT 4

SHOP OPERATIONS HAZARD ANALYSIS

METHODS	Lecture, Demonstration, Class Participation	LENGTH: 2 Hours
PURPOSE	To introduce and demonstrate the use of hazard analysis as a method for locating and controlling hazards associated with industrial/vocational school shop curricula, training methods, operations and procedures.	
OBJECTIVES	To enable the participant to: 1. Understand the purposes and uses of hazard analysis 2. Understand the steps required to set up and conduct a hazard analysis 3. Develop solution alternatives from hazard analysis information 4. Contribute to the development of a model of a shop operations hazard analysis.	
SPECIAL TERMS	1. Shop Operations Hazard Analysis 2. Process 3. Operation 4. Task 5. Triggering Event 6. Flow Diagram	
INSTRUCTOR	Overhead Transparencies of Flow Diagrams and Analyses Formats Overhead Projector 35 mm Slides of Operational Steps Slide Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and OSHA Formats	

UNIT 4

SHOP OPERATIONS HAZARD ANALYSIS

INTRODUCTION

In Unit 3 we discussed the five essential processes that must be present in order to reduce or eliminate hazards in the industrial/vocational education setting. In this unit we will explore a technique known as hazard analysis, which, if properly employed, can make any hazard control program even more effective.

How Instructors and Supervisors Acquire Knowledge of Safe and Correct Methods and Techniques

Instructors and supervisors acquire knowledge of correct and safe methods and techniques from their own individual experimentation and experience, as well as from their observation of accidents and near-accidents occurring within the school shop. Naturally, the more knowledge an instructor or supervisor acquires, the better his instruction and overall control of the shop setting. One of the benefits of hazard analysis is that it is designed to increase a participant's knowledge of potential hazards associated with various shop operations. Hazard analysis is a technique that will:

Benefits of Hazard Analysis

1. improve instructional methods
2. provide for the best selection and placement of tools, equipment and machinery
3. increase effectiveness of shop processes, operations and tasks
4. reduce the potential for accidents and injuries.

In Unit 3 we stressed the importance of acquiring accurate hazard information and communicating such information so that its significance is understood and action is taken to eliminate or at least reduce hazards in the shop setting. Hazard analysis has proven itself an excellent tool in facilitating the hazard identification and evaluation process.

Shop Operations Hazard Analysis

General Uses of Hazard Analysis

Shop Operations Hazard Analysis (SOHA) is an adaptation of hazard analysis commonly used in industry.[1] It is a technique which assists instructors and supervisors in:

Uncovering Hazards Which May Have Been Overlooked

1. uncovering hazards that may have been overlooked in the original design or setup of a particular process, operation or task but that have the potential to cause personal injury, damage to tools, machinery or equipment, and waste of materials

Locating Hazards Which Develop after Operations Have Started

2. locating hazards that may have developed after a shop operation or task was instituted

Determining Essential Operational Requirements and Student Qualifications

3. determining the essential factors in and requirements for specific job processes, operations and tasks and the student qualifications required to perform work in a safe and productive manner

Reviewing Curricula

4. reviewing curricula and training and educational approaches to uncover areas which warrant improvement

Identifying Educational and Training Needs

5. identifying educational and training needs of students.

RESULTS OF HAZARD ANALYSIS

To summarize, hazard analysis can be used to:

Modify Operations

1. modify shop processes, operations and tasks

Produce Information for Establishing Effective Controls

2. produce information essential in establishing effective control measures (adoption of procedural changes, special procedures, safety devices such as machine guards, protective equipment, etc.)

Locate and Arrange Equipment and Machinery Properly

3. locate and arrange equipment and machinery so that students and instructors will not be exposed to unnecessary hazards

Identify Situational Hazards

4. identify situational hazards (in facilities, equipment, tools, materials and operational events)

Identify Human Factors

5. identify human factors responsible for accident situations (student capabilities, activities, limitations, etc.)

Identify Exposure Factors

6. identify exposure factors that contribute to injury and illness (contact with hazardous substances, materials or physical agents)

Identify Physical Factors

7. identify physical factors that contribute to accident situations (noise, vibration, insufficient illumination, etc.)

Determine Appropriate Inspection and Maintenance Standards

8. determine appropriate inspection methods and maintenance standards needed for safety.

KEY DEFINITIONS

Usually the words "process," "operation" and "task" are used interchangeably. In the language of hazard analysis, however, these terms have specific meanings.

Process

Process means all operations and tasks which unite human effort and physical and economic resources in order to accomplish a specific purpose (e.g., turning roundstock between centers on a metal lathe).

Operation

Operation means a major step in the overall process (e.g., sharpening the cutting tool for use in turning roundstock between centers).

Task

Task means a sub-set required to accomplish an operation (e.g., placing a cutting tool in a holder prior to sharpening tool on grinder).

As a general rule, there should be hazard analysis for every existing and new process and operation conducted in the school shop.

WHO SHOULD PARTICIPATE IN HAZARD ANALYSIS?

A hazard analysis, to be fully effective and reliable, should represent the input of as many different viewpoints as possible. Every person familiar with a process or operation has acquired insights concerning problems, faults and situations which can cause accidents. These insights need to be recorded along with those of the initiator of hazard analysis.

Instructor

Department Heads; Maintenance Personnel; Members of Safety and Health Committees

Foremen and Journeymen in Industry

In addition to the instructor, who will initiate the analysis of shop processes, operations and tasks, others are in a position to give assistance. Department heads, maintenance personnel, and members of the school's safety and health committees all can contribute valuable information. The instructor or supervisor may want to contact foremen and journeymen in industry to share their views on hazards and other problems associated with a specific shop process.

Students

Last but certainly not least are the students. There are three good reasons for encouraging student participation when conducting hazard analysis. First, students may have observed problems or been involved in near-misses which can shed light on a hazardous situation overlooked by everyone else. Second, student involvement in the analysis process reinforces the legitimacy and importance of safety and health in the shop, helping the students to see where hazards exist and what can be done about them.

Such knowledge will accompany students when they enter industry. Finally, students are more likely to conform to procedures that they have helped to develop.

SELECTING THE PROCESSES, OPERATIONS AND TASKS TO BE ANALYZED

Many processes, operations and tasks conducted in the shop are good candidates for hazard analysis because they have the potential to cause accident situations. Some, however, are worthier candidates than others. In determining which processes, operations and tasks receive priority for analysis, the considerations are:

Frequency of Accidents

1. *Frequency of Accidents.* An operation or task that has repeated accidents associated with its performance is a good candidate for analysis, especially if different students have the same kind of accident while performing the same operation or task.

Potential for Injury

2. *Potential for Injury.* Some processes and operations may have a low accident frequency but a high potential for major injury; e.g., tasks on the grinder conducted without the use of a tool rest or tongue guard.

Severity of Injury

3. *Severity of Injury.* A particular process, operation or task may have a history of serious injuries and is a worthy candidate for analysis even if the frequency of such injuries is low.

New or Altered Processes and Operations

4. *New or Altered Processes and Operations.* As a general rule, whenever a new process, operation or task is created or an old one altered because of machinery or equipment changes, etc., a hazard analysis should be conducted. For maximum benefits the hazard analysis should be done while the process or operation is in the planning stages.

Excessive Material Waste or Tools and Equipment Damage

5. *Excessive Material Waste or Damage to Equipment.* Processes or operations which produce excessive material waste and/or damage to tools and equipment are candidates for hazard analysis. The same problems which are causing excessive waste and damage may be the ones which could, given the right situation, cause injuries.

STEPS IN CONDUCTING A HAZARD ANALYSIS

Once the processes have been identified for analysis, the following steps are taken:

1. The process is broken down into its operations and tasks.
2. An analysis format is devised or acquired.
3. Potential hazards are identified.

4. Recommendations for safe operations are developed.[2]

STEP ONE:
BREAKING PROCESS DOWN INTO ITS OPERATIONS AND TASKS

Before the search for hazards begins, a process must be broken down into a sequence of major operations and tasks, each describing what is being done.

Don't Be Excessively Detailed

In performing the first step, two errors are commonly made. One is breaking the process down into an overly detailed and unnecessarily large number of tasks. The result is an analysis so cumbersome that its major benefits are lost.

Don't Be Too General

The second common error is making the operational breakdown so general that important steps are not recorded. Consequently, hazards associated with these steps remain hidden and adequate control measures cannot be identified.

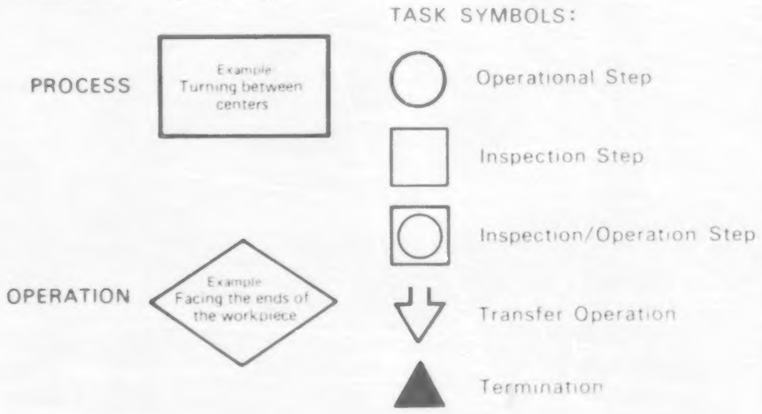
In breaking a process down, the instructor or supervisor needs to determine what operation comes first in the overall process, what major operations follow and what major tasks complete the operation. In defining the major operations and tasks for a particular process, the instructor or supervisor will find his job easier if he records his thinking process on paper in the form of a flow diagram.

Figures 1 and 6 in the Appendix illustrate complete flow diagrams of two operations, "Drilling Stock" and "Dressing the Grinding Wheel." In constructing these flow diagrams, the analyst concentrated on recording the important tasks which the operation demands.

Instructor Note:
Instructor uses visual aid of a flow diagram.

Flow diagrams can be made readily by using various symbols which define what is taking place throughout the flow of operations and tasks. The following symbols are most commonly used in industrial engineering.

Symbols for Flow Diagram Construction


TASK SYMBOLS:
PROCESS
Example
Turning between centers
Operational Step
Inspection Step
Inspection/Operation Step
OPERATION
Example
Facing the ends of the workpiece
Transfer Operation
Termination

STEP TWO: ACQUIRE HAZARD ANALYSIS FORMAT

As the analyst is working his way through a hazard analysis, he will find it practical to record his information on a format designed to maintain consistency, clarity and logic.

Table 3, "Shop Operations Hazard Analysis Format," has been devised to assist the instructor and supervisor in recording important information pertinent to the analysis. The analysis format is divided into ten sections, each reserved for specific information:

Sections of Format

1. *Process/Equipment* (e.g., turning between centers/machine lathe)
2. *Major Operations*— operations required to complete the process (e.g., sharpening cutting tools)
3. *Task*—student activities required to complete an operation (e.g., starting the grinder)
4. *Potential Hazard*—situation which, when triggered by factors in the shop setting, has the potential to cause an accident (e.g., grinder tool rest adjusted more than 1/8" or 3 mm. from wheel)
5. *Condition Triggering Hazard into an Accident*—conditions brought about by human error, situational or environmental factors which cause a hazardous situation to result in an accident situation (e.g., cutting tool holder getting caught between abrasive wheel and tool rest)
6. *Hazard Consequence Classification*—assessment of hazardous consequence (see previous unit):

   I — Catastrophic
   II — Critical
   III — Marginal
   IV — Negligible

7. *Hazard Probability Category*—assessment of the probability of hazard resulting in an accident situation (see previous unit):

   A — Probable
   B — Reasonably Probable
   C — Remote
   D — Extremely Remote

8. *Shop Procedural Requirements*—actions to be taken to eliminate or reduce hazards in the shop (e.g., tool rests are

TABLE 3

SHOP OPERATIONS HAZARD ANALYSIS FORMAT

PROCESS / EQUIP	MAJOR OPERATIONS	TASK	POTENTIAL HAZARD	CONDITIONS TRIGGERING HAZARD INTO ACCIDENT	HAZ CL	HAZ PROB	SHOP PROCEDURAL REQUIREMENTS	SAFETY & PPE REQ	SPECIAL INSTRUCTIONS

to be adjusted to no more than 1/8" or 3 mm. from the abrasive wheel)

9. *Safety and Personal Protective Equipment Requirements*—necessary items required to reduce the possibility of injuries and illnesses while performing shop operations and tasks (e.g., eye and face protection, sleeves rolled up, rings removed)
10. *Special Instructions*—special procedures or actions required to ensure safety and health in the shop (e.g., unbalanced and wobbly grinder wheel must be reported to instructor).

STEP THREE: IDENTIFY HAZARDS AND POTENTIAL ACCIDENTS

After selecting the process or operation worthy of analysis, breaking the process down into operations and tasks, and obtaining an analysis format for recording information acquired during the analysis, the analyst is now ready to identify the potential hazards and conditions which trigger the hazard into an accident situation.

Potential hazards not only will be associated with human, situational and environmental factors but also will be associated with the process, operations and tasks under examination. For each of the tasks identified, the analyst needs to ask the following questions:

1. Is there a danger of striking against, being struck by, or otherwise making injurious contact with an object?
2. Can the student be caught in, on, or between the object?
3. Can he slip or trip? Can he fall on the same level or to another?
4. Can he strain himself by pushing, pulling or lifting?
5. Is the environment hazardous (noise, heat, cold, toxic gas, fumes, vapor, mist, dust)?[3]

Accident Causes:

To assist the analyst in identifying hazards associated with a particular operation or task, a review of the following list of the more basic causes of accidents can be of value:

Inadequate Instruction and Inspection

1. failure to give necessary instruction, giving incorrect instructions, inspections not made according to an acceptable schedule

2.	failure of person in charge to properly plan or supervise operations and tasks	Failure to Supervise
3.	failure to plan or establish safe work practices	Failure to Establish Safe Work Practices
4.	use of unsafe methods	Unsafe Methods
5.	inexperienced or unskilled students working beyond their capabilities	Inexperience
6.	failure to maintain order and discipline in the shop	Failure to Maintain Order and Discipline
7.	failure to enforce safety and health rules and regulations	Failure to Enforce Rules and Regulations
8.	improper design, construction or layout of equipment, tools and machinery	Improper Design, Construction and Layout
9.	unsafe housekeeping, poor ventilation, inadequate lighting, etc.	Unsafe Housekeeping, Ventilation, Lighting, etc.
10.	protective devices not provided or proper equipment and tools not provided	Protective Devices or Proper Equipment and Tools Not Provided
11.	failure to maintain tools, equipment and machines	Failure to Maintain Tools and Equipment
12.	instructions not followed	Instructions Not Followed
13.	equipment or safety devices not properly inspected or maintained	Not Properly Inspecting and Maintaining Equipment or Safety Devices
14.	failure to use protective devices which have been provided	Failure to Use PPE
15.	students using protective devices with defects or incapable of providing sufficient protection.	Using Defective Safety Devices

Controlling Destructive Effects of Hazards

Once the hazards have been identified to the extent that knowledge and experience allows, the analyst must devote his attention to hazard control strategies. In this approach the analyst considers all possibilities to eliminate the potentially hazardous situation from occurring. Possibilities include changing tools and equipment or substituting less toxic materials for hazardous ones.

The second general approach to controlling the destructive effects of hazards uncovered during analysis is to reduce the possibility of an injury if an accident does occur. For example, if the potential of a grinding wheel exploding exists, then action must be taken to protect the student from injury by installing a shield or guard. Another alternative might be to decrease exposure to the hazard by removing from the path of the hazard those students who are not required to be there to perform a task. Personal protective equipment is selected either as a last alternative or as a secondary protection to be used along with machine guards, etc.

Instructor Note:

At this point the instructor refers to the Appendix for instructions on using a completed hazard analysis format.

After completing those instructions, the instructor finishes the unit by reviewing how the results of hazard analysis can be used to upgrade overall shop processes, operations and tasks.

STEP FOUR: DEVELOP SOLUTIONS

The final step in the hazard analysis process is to develop recommendations for safe operations and work tasks to prevent the occurrence of accidents. The principal solutions are:

1. Find a new way to perform the operation or task.
2. Remove or alter the physical and environmental conditions that create the hazards.
3. Change procedures.[4]

A New Operational Method

To find an entirely new way to perform an operation or task, it is necessary to determine the objective of the operation and then analyze the various ways of reaching this goal to see which way is safest.

Change in Physical/Environmental Conditions

If a new way cannot be found for the operation or task, then this question should be asked: What change in physical conditions (e.g., tools, materials, equipment, location) or environmental conditions (e.g., noise, ventilation systems) will eliminate the hazard or prevent the accident?

Changes in Tasks

The third solution in eliminating or reducing hazards in the school shop is to investigate changes in the tasks each student must perform to complete an operation. The analyst should determine:

- what the student can do to eliminate the hazard or prevent a potential accident

- how the student should do it.

Instructions Must Be Specific and Realistic

Instructions must be specific and concrete if new procedures and work tasks are to be effective. Vague precautions such as "be careful," "don't make mistakes," "do what you are told," are useless. Instructions should state clearly what to do and how to do it, using such action words as "remove," "adjust," and "insert." Sometimes instructions will call attention to potential malfunctions or hazards; e.g., "remove small chips with brush instead of with hands."

Example

Suppose the hazardous situation in question concerns the possibility that a student may be injured while sharpening a tool on the grinder because the tool rest is not adjusted properly. What specific directions should be given to reduce the possibility of an accident?

Recommendation 1: "Make certain that the cutting tool does not get pulled down into the space between the tool rest and the abrasive wheel." This recommendation is a poor one. It does not tell the student what to do to prevent the cutting tool from being caught in the space between the tool rest and the wheel.

Recommendation 2: "Before sharpening a cutting tool on the grinder, be sure to adjust the tool rest to within 1/8" or 3 mm. of the abrasive wheel and maintain this distance by adjusting the tool rest as the wheel wears down." This recommendation is much better. It tells what to do and specifies how to do it.

With the techniques of hazard analysis, the industrial/vocational education instructor and supervisor can create a more effective, thorough safety and health program.

NOTES

1. A good introduction to hazard analysis is "Evaluation and Control of Workplace Accident Potential,' NIOSH, January 1978.

2. The hazard analysis technique described in the following pages was developed and tested by RJF Associates, Inc., in 1969.

3. See *Accident Prevention Manual for Industrial Operations*, 7th ed. (Chicago: National Safety Council, 1974), p. 114.

4. *Accident Prevention Manual*, p. 114. The chapter "Removing the Hazard from the Job" (pp. 104–120) gives helpful information for accomplishing Step 4 in the hazard analysis process.

QUESTIONS AND ANSWERS

1. What is hazard analysis?

Hazard analysis is a technique designed to increase a participant's knowledge of potential hazards associated with various shop operations in order to:

a. improve instructional methods

b. provide for the best selection and placement of tools, equipment and machinery

c. increase effectiveness of shop processes, operations and tasks

d. reduce the potential for accidents and injuries.

2. - Name three primary uses of the hazard analysis technique.

Shop Operations Hazard Analysis is a technique which assists instructors and supervisors in (any three from among the following):

a. uncovering hazards which may have been overlooked

b. locating hazards which develop after operations have started

c. determining essential requirements and student qualifications for specific operations

d. reviewing curricula and training and educational approaches to uncover areas which warrant improvement

e. identifying educational and training needs of students.

3. **Name three factors determining which processes and operations are candidates for hazard analysis.**

Any three from among the following:

a. frequency of accidents

b. potential for injury

c. severity of injury

d. new or altered processes and operations

e. excessive material waste or damage to tools and equipment.

4. **What are the four processes in hazard control?**

a. Break down the process into its operations and tasks.

b. Devise or acquire a hazard analysis format.

c. Identify potential hazards.

d. Develop recommendations for safe operations.

5. **What are three ways to prevent accidents from recurring?**

a. Find a new way to perform the operation or task.

b. Remove or alter the physical and environmental conditions that create the hazard.

c. Change procedures.

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Hammer, Willie, *Handbook of System and Product Safety*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632. 1972.

U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, "Evaluation and Control of Workplace Accident Potential," January 1978.

APPENDIX

Instructor Note: USING A COMPLETED HAZARD ANALYSIS FORMAT

Figure 1. "Drilling and Countersinking Stock on Drill Press"
Hazard Analysis Flow Diagram

Table 4. "Drilling and Countersinking Stock on Drill Press"
Shop Operations Hazard Analysis Format

Figure 6. "Dressing the Grinding Wheel"
Hazard Analysis Flow Diagram

Table 4 (continued). "Dressing the Grinding Wheel"
Shop Operations Hazard Analysis Format

INSTRUCTOR NOTE: USING A COMPLETED HAZARD ANALYSIS FORMAT

At the point indicated on page 4-20, the instructor is to use that portion of the completed Shop Operations Hazard Analysis format which illustrates an analysis of one operation, in this case drilling and countersinking stock on a drill press, or one process, in this case turning between centers. The format distributed to participants should not display hazard consequence classification or hazard probability categories. The instructor asks the participants to estimate the consequence classification and the probability of identified hazards resulting in an accident situation. When all estimates have been recorded on the chalk board, the instructor displays his estimates and presents the rationale behind them.

The instructor now distributes in its entirety the sample Shop Operations Hazard Analysis format. He divides the group into teams of five, has each team appoint a leader, and explains that each team will devote the next hour to attempting to add to and improve the information contained on the analysis format. Each team is to concentrate on a different major operation. At the conclusion of one hour, each team leader summarizes for the class the findings of his team, the rationale behind its recommendations, and any problems members had in understanding the technique. All suggestions are recorded on the chalk board. When the list is complete, the group, under the leadership of the instructor, begins to decide:

1. which items on the list should be included along with the others on the previously developed analysis formats
2. how the information contained on the formats can be strengthened. The instructor then returns to the lesson (p .4-21) to finish the unit.

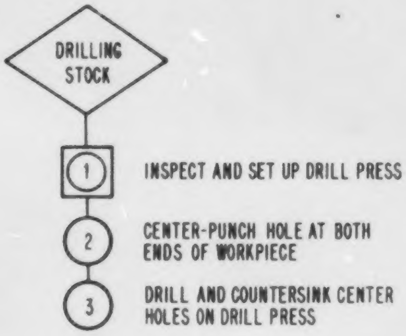
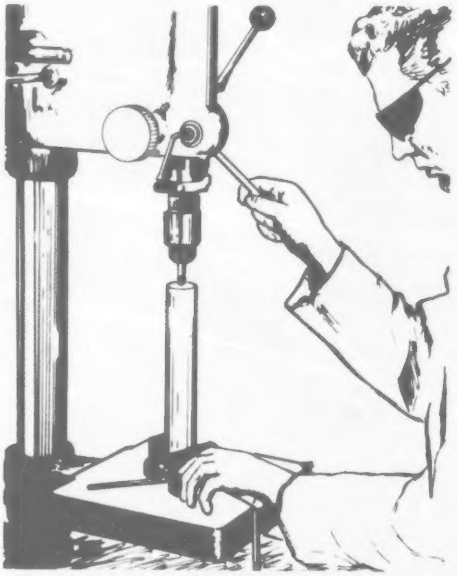

DRILLING STOCK
1
INSPECT AND SET UP DRILL PRESS
2
CENTER-PUNCH HOLE AT BOTH ENDS OF WORKPIECE
3
DRILL AND COUNTERSINK CENTER HOLES ON DRILL PRESS

Figure 1

TABLE 4

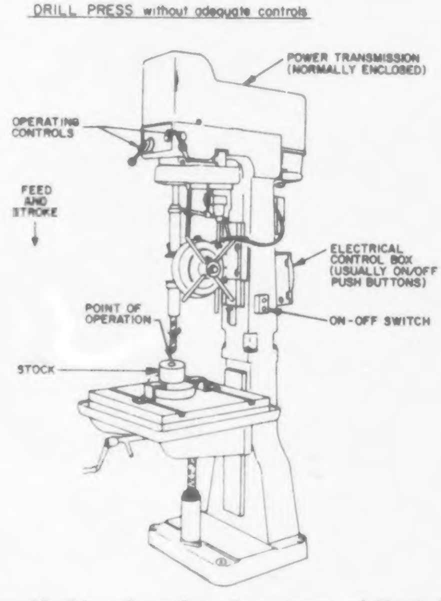
SHOP OPERATIONS HAZARD ANALYSIS FORMAT

PROCESS / EQUIP	MAJOR OPERATIONS	TASK	POTENTIAL HAZARD	CONDITIONS TRIGGERING HAZARD INTO ACCIDENT	HAZ CL	HAZ PROB	SHOP PROCEDURAL REQUIREMENTS	SAFETY & PPE REQ	SPECIAL INSTRUCTIONS
		① Inspect and set up drill press	Defective chuck, switches, clamps, etc.	Operating drill press with defective parts	II	B	Do not operate drill press if defective. Attach "do not operate" tag.		
		② Center punch hole at both ends of workpiece	Workpiece not securely clamped while center punching holes	Workpiece slipping from underneath punch when punch is hit with hammer	II	B	Workpiece is to be secured in vise before striking punch. Select No. 2 combination drill & countersink (Fig. 2)		
		③ Drill and countersink center holes on drill press	Placing workpiece in position for drilling without clamping in vise	Bringing drill in contact with workpiece	II	B	Workpiece is to be secured in vise before drilling holes		
			Leaving chuck wrench in chuck at time when machine is started	Starting drill press	I	A	Chuck wrench to be removed from chuck prior to starting machine		
			Stop-start buttons not located within easy reach of operator, causing student to reach behind or alongside moving part or not being able to shut off machine in emergency (Figs. 3, 4)	Starting machine; having having to shut machine off (normally); having to shut machine off in emergency	II	B	Stop-start buttons to be located within easy access of operator	Stop-start buttons color identified with bright colors; emergency disconnect switch required	



Drilling the center holes on the end of the workpiece on a drill press. Reprinted from John L. Feirer, *General Metals,* 2nd ed. (New York: McGraw Hill, 1959), p. 285, by permission of McGraw Hill.

Figure 2


DRILL PRESS without adequate controls
POWER TRANSMISSION (NORMALLY ENCLOSED)
OPERATING CONTROLS
FEED AND STROKE
ELECTRICAL CONTROL BOX (USUALLY ON/OFF PUSH BUTTONS)
POINT OF OPERATION
ON-OFF SWITCH
STOCK

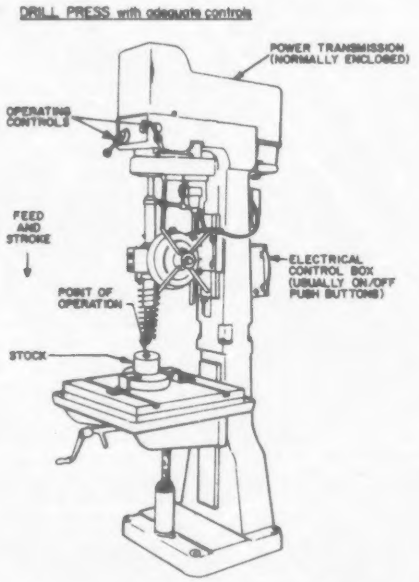
Adapted from *Machine Guarding—Assessment of Need,* NIOSH, HEW Publication No. (NIOSH) 75-173, June 1975. p. 51.

Figure 3

TABLE 4 (Continued)

SHOP OPERATIONS HAZARD ANALYSIS FORMAT

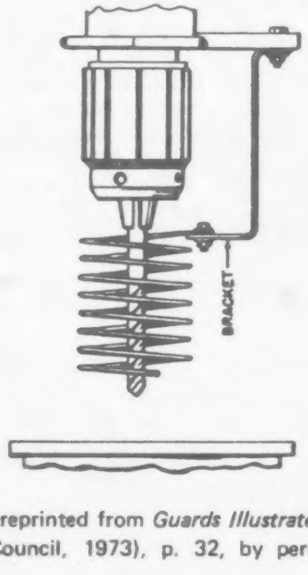
PROCESS / EQUIP	MAJOR OPERATIONS	TASK	POTENTIAL HAZARD	CONDITIONS TRIGGERING HAZARD INTO ACCIDENT	HAZ CL	HAZ PROB	SHOP PROCEDURAL REQUIREMENTS	SAFETY & PPE REQ	SPECIAL INSTRUCTIONS
			Student with long hair, long-sleeved shirt, neck-tie or gloves working on activated drill press	Clothing, hair, etc., coming in contact with drill or chuck while machine is in operation	II	A	Sleeves rolled up; hair in nets or tied back; no neckties; no gloves used while press is in operation	Use telescoping guard (see Fig. 5)	
			Rotating drill in chuck	Student's hand or arm coming in contact with with spinning drill	II	B	Student to keep full concentration on operation		
			Drill breaking during drilling mode	Excessive pressure placed on drill and/or not lubricating drill	II	A	Drill should not be jammed down into stock; slow and even pressure required; lubricate	Face shield and/or goggles	Drills inspected for cracks prior to drilling
			Flying metal chips	Working on drill press	II	B	If excessive chips begin to fly from workpiece, shut off machine and call for instructor assistance	Face shield and/or goggles	
			Metal chips created during drilling operation	Student attempting to remove chips while machine is running	II	B	Drill press is to be shut off and chips cleaned with bursh	Face shield and/or goggles	
			Drill sticks in work	Drilling stock	III	B	Stop spindle; free by hand		
			Pinch points at belts	Adjusting belts	II	B	Always stop press before adjusting belts		


DRILL PRESS with adequate controls
POWER TRANSMISSION (NORMALLY ENCLOSED)
OPERATING CONTROLS
FEED AND STROKE
ELECTRICAL CONTROL BOX (USUALLY ON/OFF PUSH BUTTONS)
POINT OF OPERATION
STOCK

Drill press adapted from *Machine Guarding—Assessment of Need,* NIOSH, HEW Publication No. (NIOSH) 75-173, June 1975, p. 51.

Figure 4

TELESCOPING GUARD



Safety mechanism reprinted from *Guards Illustrated,* 3rd ed. (Chicago: National Safety Council, 1973), p. 32, by permission of National Safety Council.

Figure 5

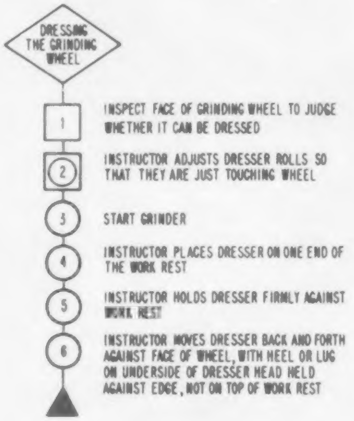
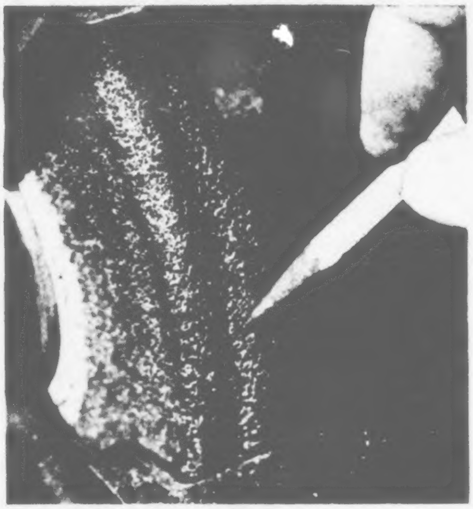

DRESSING THE GRINDING WHEEL
1
INSPECT FACE OF GRINDING WHEEL TO JUDGE WHETHER IT CAN BE DRESSED
2
INSTRUCTOR ADJUSTS DRESSER ROLLS SO THAT THEY ARE JUST TOUCHING WHEEL
3
START GRINDER
4
INSTRUCTOR PLACES DRESSER ON ONE END OF THE WORK REST
5
INSTRUCTOR HOLDS DRESSER FIRMLY AGAINST WORK REST
6
INSTRUCTOR MOVES DRESSER BACK AND FORTH AGAINST FACE OF WHEEL, WITH HEEL OR LUG ON UNDERSIDE OF DRESSER HEAD HELD AGAINST EDGE, NOT ON TOP OF WORK REST

Figure 6

BADLY RUTTED GRINDING WHEEL



When an abrasive wheel is rutted, worn or out of balance, it can damage the machine, injure the operator and produce poor work. Dressing the grinding wheel means removing a large area of the face to restore the wheel to good condition. If a wheel cannot be balanced by truing and dressing, it should be removed from service. Reprinted with permission from *Accident Prevention Manual for Industrial Operations—Engineering and Technology,* 8th ed. (Chicago: National Safety Council, 1980), p. 362.

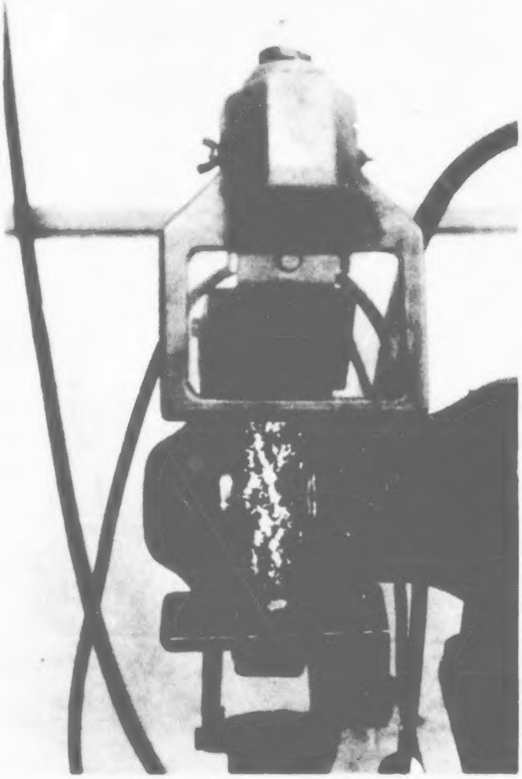
Figure 7

TABLE 4 (Continued)

SHOP OPERATIONS HAZARD ANALYSIS FORMAT

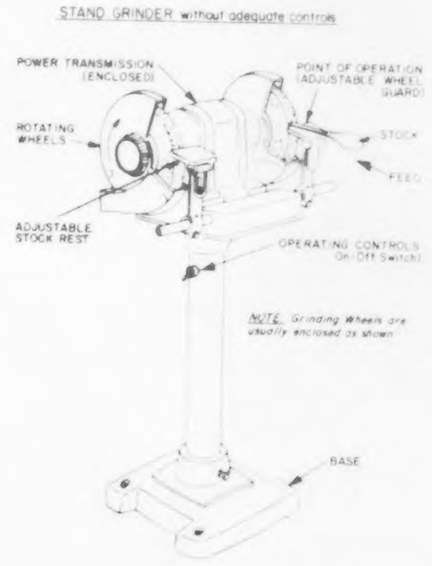
PROCESS / EQUIP	MAJOR OPERATIONS	TASK	POTENTIAL HAZARD	CONDITIONS TRIGGERING HAZARD INTO ACCIDENT	HAZ CL	HAZ PROB	SHOP PROCEDURAL REQUIREMENTS	SAFETY & PPE REQ	SPECIAL INSTRUCTIONS
Turning Between Centers/Pedestal Grinder	Dressing the Grinding Wheel	1 Inspect face of grinding wheel to judge whether it can be dressed (Figs. 7, 8)							Round off wheel edges with hand stone before dressing to to prevent edges from chipping
		② Instructor adjusts dresser rolls so that they are just touching wheel	Misalignment causing wheel to come in contact with dresser rolls when grinder is started	Wheel binding against dresser rolls and possibly degrading when grinder is started	II	A	Adjust work rest so that dresser rolls are just touching grinding wheel	Face shield, work apron	
		③ Start grinder	Flying chips or debris coming from wheel	Starting grinder	II	B	Operator should stand to one side of grinder when starting machine. Upper peripheral guard must be in place	Face shield	Point of operation guards (Figs. 9, 10)
			Wheel or spindle ends catching clothing	Starting grinder	II	A	Roll up or clip sleeves		
			Excessive vibration	Not dressing wheel properly	II	A	Shut down equipment	Equipment adequately grounded or GFCI	
			Wheel exploding	Running grinder at excessive RPM with crack or other defect	I	B	Following instructions for RPM		

GRINDING WHEEL IN NEED OF DRESSING



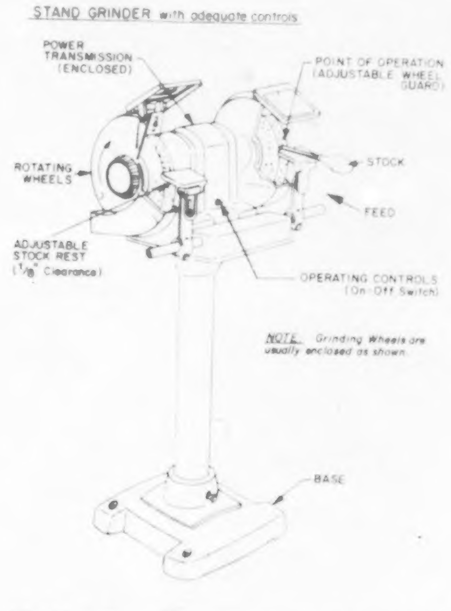
This illustration shows a wheel loaded with aluminum particles. It needs to be dressed. Photography courtesy of Robert J. Firenze.

Figure 8


STAND GRINDER without adequate controls
POWER TRANSMISSION (ENCLOSED)
POINT OF OPERATION (ADJUSTABLE WHEEL GUARD)
ROTATING WHEELS
STOCK
FEED
ADJUSTABLE STOCK REST
OPERATING CONTROLS (On-Off Switch)
NOTE. Grinding Wheels are usually enclosed as shown
BASE

Adapted from *Machine Guarding–Assessment of Need*, NIOSH, HEW Publication No. (NIOSH) 75-173, June 1975, p. 46.

Figure 9


STAND GRINDER with adequate controls
POWER TRANSMISSION (ENCLOSED)
POINT OF OPERATION (ADJUSTABLE WHEEL GUARD)
ROTATING WHEELS
STOCK
FEED
ADJUSTABLE STOCK REST (1/8" Clearance)
OPERATING CONTROLS (On-Off Switch)
NOTE. Grinding Wheels are usually enclosed as shown.
BASE

Adapted from *Machine Guarding–Assessment of Need*, NIOSH, HEW Publication No. (NIOSH) 75-173, June 1975, p. 46.

Figure 10

TABLE 4 (Concluded)

SHOP OPERATIONS HAZARD ANALYSIS FORMAT

PROCESS / EQUIP	MAJOR OPERATIONS	TASK	POTENTIAL HAZARD	CONDITIONS TRIGGERING HAZARD INTO ACCIDENT	HAZ CL	HAZ PROB	SHOP PROCEDURAL REQUIREMENTS	SAFETY & PPE REQ	SPECIAL INSTRUCTIONS
		④ Instructor places dresser on one end of the work rest					Make sure that lugs of dresser are against edge of work rest		Use dressing wheel approved for job. Never use lathe cutting tool.
		⑤ Instructor holds firmly against edge of work rest	Excessive pressure on wheel	Operator exerting ing excessive pressure on dresser rolls	II	A	Exert only sufficient pressure to allow dresser to remove a small amount of abrasive wheel at one pass; roll up or clip sleeves; remove rings	Face shield; hair nets	Hands should be free of grease or oil Machine guard in down position
		⑥ Instructor moves dresser back and forth against face of wheel, with heel or lug on underside of dresser head held firmly against edge, not on top of work rest	See ⑤	See ⑤	II	A	See ⑤	See ⑤	See ⑤ Round off wheel edges with hand stone after dressing to prevent edges from chipping

UNIT 5

SAFETY COMMITTEES

METHODS	Lecture LENGTH: 30 Minutes
PURPOSE	To examine the functions and uses of safety committees in the industrial/vocational education safety and health program.
OBJECTIVES	To introduce the participant to: 1. The value of safety committees 2. The types of committees 3. The way to organize and operate committees.
SPECIAL TERMS	1. Safety and Health Policy Committee 2. Shop Safety and Health Committee
INSTRUCTOR MATERIALS	Lesson Plan Overhead Transparencies, Projector and Screen Chalk Board/Chalk
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials

Unit 5

SAFETY COMMITTEES

INTRODUCTION

As we discussed in Unit 3, the reduction or elimination of hazards in the industrial/vocational education shop cannot be delegated to a single group but instead must involve the active participation and cooperation of many key people in the school organization. Like any other kind of committee, the safety and health committee can either provide a valuable service or end up as nothing more than a social circle which is neither productive nor efficient. What makes one committee highly effective while another fails? The answer lies in part with the original purpose of the committee, how well it is structured and staffed, and the support it receives while carrying out its responsibilities.

PURPOSE OF UNIT

In this unit we will examine the basic types of safety and health committees used in industrial/vocational education. We will explore what they should be, how they should work and how they should be organized and managed in order to ensure that they function productively and efficiently.

WHAT IS A SAFETY AND HEALTH COMMITTEE?

A safety and health committee is a group appointed to aid and advise the school administration on matters of safety and health pertaining to shop operations. In addition, it performs essential monitoring, educational, investigative and evaluative tasks. The committee, depending on its type, is composed of members of the school administration, instructors, department heads, maintenance personnel and students.

If the industrial/vocational education program has any formal safety program at all, it is usually small and limited. Too often, staff must sandwich in safety and health with other activities. Such a system lacks coordination; each person delegated responsibility for safety and health is left pretty much on his own to provide for and maintain a safe and healthy shop setting. The results of such a program are usually less than desirable.

VALUE OF COMMITTEES

To establish and maintain a safety and health program of high quality, the full cooperation of everyone in the school organization is required. The safety and health committee is a vehicle for

Committee is Vehicle for Providing Cooperation

obtaining this cooperation while effectively and efficiently distributing the work load so that a few people in the school do not have to carry the whole safety and health burden by themselves. Committees provide an official channel and forum for combining the knowledge and experience of many people in order to accomplish the objectives of reducing hazards and losses.

Committees Provide Channels for Action

Safety and health committees provide a means whereby hazard information and suggestions for hazard control can travel between the shop and the school administration. Committee members can translate their ideas into actions. Because the information flow is facilitated, administrators can process problems and take action more expediently.

Committees Provide Closer Relationships

Committees by their very nature encourage a close relationship between school administrators, department heads, instructors and students. The benefits of this close relationship can be found not only in greater attention to safety and health and a finer understanding of hazard control but also in higher school morale. Because they facilitate communication, safety and health committees provide an excellent means for maintaining school morale at a high level.

Many Heads Are Better Than One

Perhaps the greatest value of all is that committees force many minds to address a problem simultaneously. With so much "thinking power" working on problems, effective solutions are produced.

TYPES OF SAFETY AND HEALTH COMMITTEES

There are two basic types of safety and health committees used in industrial/vocational education settings: *policy* and *shop* committees. In a smaller school these two committees may need to be combined into one group of six to eight persons, representing administration, department heads, instructors, students and maintenance personnel.

Safety and Health Policy Committee

The Safety and Health Policy Committee is composed of an assistant principal, at least one department head, at least one instructor and a teachers' association representative where applicable. The work of this committee includes:

1. identifying, defining and studying those problems which have a significant impact on the safety and health of school staff and students
2. studying safety and health implications of interdepartmental functions and of changes in procedures and processes

3. acting on or evaluating the effectiveness of recommendations from the Shop Safety and Health Committee
4. assessing recommendations in the light of appropriations and setting priorities for expending funds to improve safety and health in the school
5. reviewing and updating all school rules and regulations applicable to safety and health
6. promoting and evaluating training and education in hazard recognition and control
7. standardizing disciplinary courses of action for noncompliance with school safety and health rules and regulations
8. reviewing accident reports
9. reviewing beneficial suggestions to improve safety and health.

The Safety and Health Policy Committee also gives guidance to the Shop Safety and Health Committee, to which it refers specific tasks.

Shop Safety and Health Committee

The Shop Safety and Health Committee, unlike the Policy Committee, is the group that promotes safety and health at the shop level. It consists of department heads, instructors, maintenance personnel, student shop foremen and, when applicable, a teachers' association representative. The work of this committee includes:

1. conducting periodic shop and facility inspections to detect hazardous physical and environmental conditions, unsafe procedures and practices
2. studying and evaluating accident and injury data
3. investigating all accidents occurring in the school and preparing reports
4. conducting safety and health training and evaluation programs
5. conducting hazard analyses of all shop processes and operations

6. reviewing and upgrading shop curricula, instructional methods and materials

7. field-testing safety and health equipment and making recommendations to the Policy Committee

8. studying the implications of changes in shop processes, operations and tasks

9. recommending actions to be taken by the Policy Committee to eliminate or reduce hazards

10. considering ways and means of improving the effectiveness of rules, regulations, procedures, etc., to promote safety and health in the school

11. promoting first aid training for all school staff.

ORGANIZING COMMITTEES

The top school administrator must keep in mind two important requirements in organizing the committee: first, to keep the committee small and effective; and second, to appoint a chairman who is respected and who demonstrates interest in the area of safety and health. The administrator must impress upon the chairman that committee members, no matter how good their intentions, should be constantly motivated and encouraged to take on additional responsibilities while still maintaining their planning, instructional and evaluative duties. Thus, the person selected to chair the committee must be "sold" on the purposes of and results to be gained from a school safety and health program.

Committee Size

The ideal size of the Policy Committee would be about six people, representing administration, department heads, instructors and teachers' association representative. The committee should be structured so that the principal is an ex officio member of the Policy Committee. The Shop Safety and Health Committee, including as it does student representatives and maintenance personnel, might range in size from six to ten persons. The committees should be of manageable size so that each member will have the opportunity to participate. Committee membership should be staggered so that the term of office of all committee members does not expire at the same time, destroying the continuity of committee programs.

Educating and Training Committee Members

Committee members will for the most part need safety and health training and education before they can be effective. Consequently, school administrators must see to it that committee members receive basic instruction in the principles and techniques of hazard recognition and control. Parts of this course can be used to increase the knowledge and skill of committee members. The units on inspections, hazard analysis and accident investigations and several of the technical units are highly recommended for use in training and educating committee members.

Procedure for Recommendations

To arrive at recommendations, the safety committee needs an established procedure. In schools with only one safety and health committee, recommendations will go directly to the administration. In schools with two committees, the Shop Safety and Health Committee will make its recommendations to the Policy Committee, to which the administration has delegated its authority.

The following procedures are suggested:

1. When a committee member makes a recommendation, it should be discussed by the entire committee to determine if the recommendation is acceptable, if it needs modification before being submitted to the school administration or Policy Committee, or if it should be rejected.

2. Any recommendation regarding safety and health in industrial/vocational education must be referred directly to the Shop Safety and Health Committee. A recommendation received from outside the committee should be subject to the same procedure described above: committee discussion, leading to acceptance, modification or rejection.

3. Recommendations which have been accepted by the committee should be submitted in writing to the school administration or Policy Committee.

    a. Recommendations should state *what* is to be done, *by whom* and *when* (the date it is to be completed). Committees should avoid making recommendations to do something "at once," "as soon as possible," "when funds are available," "when convenient" and so forth. Such recommendations are either too demanding or too vague and transfer the responsibility of deciding priorities to the doer.

b. The written statement should explain *why* a course of action is recommended, information which also should be included in the committee meeting minutes. Such explanations should make clear in what way the recommended action will reduce or eliminate hazards and improve safety and health within the school.

c. *How* the recommendation is to be carried out should be stated only if "method" is a condition of the recommendation.

CONDUCTING COMMITTEE MEETINGS

Establishing a Date for Meetings

The chairman of the Shop Safety and Health Committee should establish a date and time for each committee meeting, taking into account the schedules of members. The committee should meet at least once a month and carry out assignments between meetings. The Policy Committee meets as needed, at the discretion of its chairman and the school administration.

Advance Agenda

At least five days in advance of a committee meeting, notice of the meeting and the agenda should be sent to each committee member. By receiving the agenda beforehand, committee members have time to think about the topics to be considered and organize their ideas and opinions at a leisurely pace. A good practice is to include with the agenda a copy of the minutes of the last meeting.

Duration of Meetings

Whenever possible, meetings of the Shop Safety and Health Committee should be held to one hour. In order to accomplish an entire agenda in that time, the committee chairman must take time beforehand to organize the business at hand into a tight schedule.

Role of Chairman

During committee meetings, the chairman must keep the program on course. It is easy for the chairman, as coordinator, to slip out of the leader's role and find himself doing the leg work of committee members. When the chairman steps out of his role, even for a short period of time, he frustrates the members. On the other hand, if the chairman conducts meetings in such a manner that he makes all the recommendations himself, the role of the committee is destroyed. Instead of the members jointly participating in decisions, they are forced into accepting one person's opinions. If such a situation is allowed to continue, the effectiveness of the committee will be drastically reduced and soon committee members will refuse to participate.

Rules of Order

The committee should adopt a formal set of rules to govern the conduct of the meeting.

Keeping Minutes of Meetings

Committee meetings are more productive when minutes of proceedings are kept. These minutes need not be elaborate but should be complete and informative and should be reviewed by the school principal after each meeting. Minutes taken by the committee secretary should follow a pattern similar to the following:

1. date of meeting
2. time meeting opened
3. members present
4. members absent
5. minutes of previous meeting read and approved or disapproved
6. unfinished business (including issues involving recommendations not yet resolved)
7. recommendations completed since last meeting
8. new business (including discussion of inspections and hazard analyses made)
9. new recommendations (all recommendations to be submitted on forms similar to those in Tables 1 and 2 of Unit 3)
10. listing and discussion of accidents which occurred since last meeting (date of injury, student, instructor, school employee, cause, recommendations, etc.)
11. other committee remarks
12. committee resolutions
13. time meeting adjourned and date of next meeting
14. secretary's signature
15. space for signature of reviewing official and date.

EFFECTIVENESS OF SAFETY COMMITTEES

The effectiveness of safety committees depends on several factors:

Regular Meetings and Attendance

1. Regular meeting times and regular attendance at meetings indicate interest.

Interested and Cooperative Members

2. Committee members must be sincerely interested in the school safety and health program and willing to cooperate with others to improve that program.

Recommendations Are Considered and Acted Upon

3. Committee recommendations and suggestions must be carefully considered and acted upon. If the committee becomes a show-piece with no real authority or support, it should be disbanded and a fresh start made.

Accomplishments Are Recognized

4. The committee's work and accomplishments should receive recognition, either by means of public announcement or private letters of commendation. An effective chairman will express his appreciation for the contributions and expertise of committee members.

QUESTIONS AND ANSWERS

1. What is a safety committee?

A safety committee is a group consisting of school staff and students appointed to perform essential monitoring, educational, investigative and evaluative tasks. It also aids and advises the school administration on matters of safety and health as they relate to shop operations.

2. What are the two basic types of safety committees?

Policy and shop committees.

3. What information should be included in the written recommendations of the safety committee?

The recommendations should specify *what* is to be done, by *whom*, *when* the work should be completed and *why* this course of action is necessary.

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UNIT 6

ACCIDENT INVESTIGATION TECHNIQUES

METHODS	Lecture and Demonstration LENGTH: 60 Minutes
PURPOSE	To introduce the participant to the process of accident investigation from the standpoint of its necessity, techniques, methods and benefits.
OBJECTIVES	To introduce the participant to: 1. Benefits and purposes of accident investigation 2. Techniques of conducting an accident investigation 3. Specific information to be sought in investigation 4. Techniques of conducting interviews 5. The preparation of an accident report.
SPECIAL TERMS	1. Direct Costs 2. Indirect Costs 3. Human Error
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Chalk Board/Chalk
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials

Unit 6

ACCIDENT INVESTIGATION TECHNIQUES

INTRODUCTION

In units 3 and 4 we emphasized the importance of identifying and evaluating hazards in the industrial/vocational education shop before these hazards result in accident situations. This approach suggests that, if we can locate, assess properly and counter potential accidents before they result in accidents, perhaps students and school staff will not be injured or made ill, losses will be minimized and instructional and operational methods will be more effective.

In Any Good Program Accidents Still Occur

While the idea behind this concept is sound and in fact has proven itself to be a critically desirable element of any hazard control program, there will be times when we will not be able to find and eliminate problems before accidents occur. When the accident occurs, we must be prepared to acquire through investigation as much information as possible about its cause(s) so that similar accidents can be avoided.

WHY INVESTIGATE ACCIDENTS?

There are four important reasons for investigating accidents that occur in industrial/vocational education programs.

1. To Determine Cause

The first reason is to determine the cause of the accident. Was it a matter of student error which can be corrected? Was the problem one which concerns rules or regulations? Did defective machinery or factors in the shop environment contribute to the accident? Poor machinery layout, for example, or the very design of a shop process, operation or task can contribute to an undesirable situation. During the discussion of accident causation in Unit 1, we learned that three primary factors are involved in accidents: human, situational and environmental. The accident investigator must concentrate on gathering all information which led up to the accident.

2. To Identify Ways to Prevent Similar Accidents

The second reason to investigate accidents is to identify what action can be taken and what improvements made to prevent similar accidents from occurring in the future.

The third reason is to document the facts involved in an accident

3. To Document Facts for Compensation and Litigation

for use in instances of compensation and litigation. Many times a school has been placed in an embarrassing situation when an attorney for the school or for the injured party has asked the administration to produce facts concerning an accident situation. The report produced at the conclusion of an investigation becomes the permanent record of facts involved in the accident. School administrators can breathe more easily when they know that an accident situation can be reconstructed years after its occurrence because the details of the accident have been recorded properly and accurately.

4. To Uncover Indirect Accident Causes

The fourth reason is that thorough accident investigation is very likely to uncover problems which indirectly contributed to the accident. Such information benefits accident reduction efforts. For example, a student slips on an oil spill and is injured. The oil spill is the direct cause of the accident, but a thorough investigation might reveal other factors: poor housekeeping, failure to follow maintenance schedule, inadequate supervision, faulty equipment (e.g., a lathe leaking oil), etc.

5. To Provide Information on Costs

Along with these four primary reasons for investigating accidents, there are other reasons that are peripherally important. One is that the investigation can provide information on the costs associated with accidents. Costs can be divided into two categories, direct and indirect:

Direct Costs:

1. medical expenses (doctor, hospital, etc.)
2. compensation costs
3. property damage (repairs, equipment replacement, etc.).

Indirect Costs:

1. supervisor's and instructor's time
2. liability claims, suits, etc.
3. insurance premium increases.

6. To Publicize the School's Interest in Safety and Health

Another reason for conducting a thorough investigation concerns a psychological (as opposed to a material) benefit. The investigation itself projects a good image of the school's interest in safety and health. The involvement of faculty and staff in the investigative process promotes cooperation which is vital to the overall safety and health program.

FACT-FINDING, NOT FAULTFINDING

Despite what many people believe, accident investigation is fact-finding, not a faultfinding, process. When attempting to determine the cause(s) of an accident, the novice is tempted to conclude that the person involved in the accident was at fault. But if human error is chosen when it is not the real cause, the hazard which caused the accident will go unobserved and uncontrolled. Furthermore, the person falsely blamed for causing the accident will respond to the unjustified corrective action with contempt and alienation. Such alienation will discourage future cooperation and undermine respect for the school's safety and health program. The intent of accident investigation is to pinpoint causes of error and/or defects so that similar incidents can be prevented.

Accidents Indicate That Something Has Gone Wrong

When an accident occurs, it indicates that:

- something has gone wrong in the process, operation or tasks
- someone failed to perform a task properly
- a hazardous condition existed without adequate safeguards
- a newly developed process or substance has defects and dangers which only recently have become known.

Upon determining the facts, the persons who investigate accidents are in a position to offer suggestions involving:

- improvements in engineering
- changes in processes, operations and tasks
- modifications in curriculum and instruction
- improvements in supervision
- training and education.

ALL ACCIDENTS SHOULD BE INVESTIGATED

As a general rule, all accidents, no matter how minor, are candidates for thorough investigation. Many accidents that occur in the industrial/vocational school are considered minor because their consequences are not serious. Such accidents—or "incidents," Serious Accidents Arise from Same Hazards as Minor Incidents

as some people interpret them—are taken for granted and often do not receive the attention they demand. School administrators, safety and health committees and instructors must be aware that serious accidents arise from the same hazards as minor "incidents." It is usually sheer luck that determines whether a hazardous situation results in a minor incident or a serious accident. These people also must realize that there are both immediate (direct) and underlying (indirect) causes which could indicate possible administrative failures. There are also contributing causes, those that are the product of negligence by some person or organization that permits the indirect causes to exist.

WHO SHOULD INVESTIGATE

Instructor On the Scene

Accident investigation logically begins with the instructor on the site. There are several good reasons for this:

1. The instructor is the person who is on the scene. He can most quickly size up the situation, call for assistance, isolate the hazard and write down names of eyewitnesses.

He Knows:

2. The instructor knows:

Students

   a. the students—their educational level, experience and personal characteristics

Equipment and Machinery

   b. the equipment, tools and material—how they are operated, their peculiarities, their potential to cause further damage

Environment

   c. the environment in which the student and shop machinery and equipment must function.

Interest

3. The instructor has both a personal and professional interest in student and shop safety.

However, mere physical presence, knowledge and interest do not ensure that instructors will make good accident investigators. But with experience, training and guidance, instructors will be able to make valuable contributions to the investigative process.

When instructors participate in accident investigation, their sense of involvement and responsibility increases. On the other hand, denying instructors this opportunity tends to undermine their sense of responsibility and involvement in the safety and health program and their sense of accountability for accident prevention.

Shop Safety and Health Committee

The Shop Safety and Health Committee should become directly involved with investigating serious accidents; that is, those that result in injury to students or faculty, property damage, etc. The Shop Safety and Health Committee can provide additional expertise to support and complement the specific knowledge of instructors. Its involvement indicates widespread interest in hazard control and the safety and health of staff and students. Its reports will recommend actions and improvements to keep similar accidents from recurring.

As we discussed in Unit 5, it is necessary for the Shop Safety and Health Committee to become involved with corrective action. The committee must routinely follow up its investigations to determine the status and effectiveness of corrective action and to provide the stimulus necessary for the effective functioning of the school's safety and health program. A lack of committee concern or involvement will be reflected in the students' and instructors' attitudes, resulting in an ineffective program.

WHEN TO INVESTIGATE ACCIDENTS

Immediate, on-the-scene accident investigation provides the most accurate and useful information. The longer the delay in examining the accident scene, interviewing the injured party(s) and witnesses, the greater the possibility of obtaining erroneous or incomplete information. The accident scene changes, memories fail, and people talk to each other. Whether consciously or unconsciously, witnesses may alter their initial impressions to agree with someone else's observation or interpretation.

Prompt accident investigation also expresses a feeling of concern for the safety and well-being of students and school staff.

HOW TO INVESTIGATE ACCIDENTS

Conducting an accident investigation is not simple. It can be very difficult to look beyond the incident at hand to uncover causal factors and determine the true loss potential of the occurrence and develop practical recommendations to prevent recurrence.

Consider Human, Situational and Environmental Factors

A major weakness of many accident investigations is the failure to establish and consider all factors—human, situational and environmental—that have contributed to the accident. Reasons for this failure are:

Reasons for Inferior Investigations

1. inexperienced or uninformed investigator
2. reluctance of the investigator to accept responsibility

3. narrow interpretation of environmental factors
4. erroneous emphasis on a single cause
5. judging the effect of the accident to be the cause
6. arriving at conclusions too rapidly
7. poor interviewing techniques
8. delay in investigating accident.

The trained investigator must be ready to acknowledge as contributing causes any and all factors that may have, in any way, contributed to the accident. What may at first appear to be a simple, uninvolved accident may, in fact, have numerous contributing factors, which may become more complex as analyses are completed.

Safety During Investigations

Investigators are responsible for safeguarding themselves during the investigation. The committee must consider that:

Accident Scene Can Be More Dangerous After Accident

1. In many cases the scene of an accident is more dangerous than it was prior to the accident. For example, electrical equipment may have been damaged in an accident. The investigator must make certain that the equipment is disconnected and, if necessary, locked out before he examines it.

Precautions Around Toxic Materials

2. If investigators must work around toxic materials, they should use protective measures, including special handling equipment.

Clear Understanding of Committee Members' Roles

3. Clear responsibilities should be established and delegated to safety committee members. If this is not done, confusion will exist, evidence may be lost, or further damage to the facility may occur.

Handling Physical Evidence

4. Physical evidence is sometimes mishandled, rendering such evidence useless and making it more difficult to find the cause(s) of the accident. Thus, if this evidence were needed in a legal case, the fact that it was lost or impaired would destroy its value.

During the accident investigation many questions must be answered. Because of the infinite number of accident-producing situations, contributing factors, causes, etc., it is impossible to provide a complete list of questions that will apply to all accident investigations. Here are some questions that are generally applicable and considered most often by accident investigators:

WHAT TO LOOK FOR

1. What was the injured person doing at the time of the accident? Performing an assignment? Shop maintenance? Working on a personal project? Assisting another person?
2. Was the injured working on a task he was authorized to do? Was he qualified to perform the task? Was he familiar with the process, equipment and machinery?
3. What were other students doing at the time of the accident?
4. Was the proper equipment being used for the task at hand (screwdriver instead of can opener to open a paint can, file instead of a grinder to remove burr on a bolt after it was cut)?
5. Was the injured person following approved procedures?
6. Is the process, operation or task new to the shop?
7. Was the injured person being supervised? What was the proximity and adequacy of supervision?
8. Did the injured receive hazard recognition training prior to the accident?
9. What was the location of the accident? What was the physical condition of the area when the accident occurred?
10. What immediate or temporary action(s) could have prevented the accident or minimized its effect?
11. What long term or permanent action(s) could have prevented the accident or minimized its effect?
12. Had corrective action been recommended in the past but not adopted?[1]

During the course of the investigation, the above questions should be answered to the satisfaction of the investigators. Many other questions will come to mind as the investigation continues. They also should be recorded. A model accident report will be discussed later in this unit.

CONDUCTING INTERVIEWS

Interviewing accident or injury victims and witnesses can be very difficult if the assignment is not handled properly. The individual being interviewed often is fearful and reluctant to provide the interviewer with accurate facts about the accident. The accident victim may be embarrassed, afraid of disciplinary action, or hesitant to talk for any number of reasons. A witness may not want to provide information that might place blame on friends, fellow students, a favorite instructor or possibly himself. To obtain the necessary facts during an interview, the interviewer must first eliminate or reduce fear and anxiety by developing rapport with the individual being interviewed. It is essential that the interviewer clear the air, create a feeling of trust and establish lines of communication before beginning the actual interview.

Once such rapport has been developed, the following five-step method should be used during the actual interview:

Discuss Purpose of Investigation

1. Discuss the purpose of the investigation and the interview (fact-finding, not faultfinding).

Have Individual Relate His Own Version

2. Have the individual relate his version of the complete accident with minimal interruptions. If the individual being interviewed is the one who was injured, ask him to explain where he was, what he was doing, how he was doing it and what happened. If practical, have the injured person or eyewitness explain the sequence of events which occurred at the time of the accident. When someone is at the scene of the accident, he will be able to relate facts that might otherwise be very difficult to explain.

Ask Questions When Necessary

3. Ask questions to clarify facts or fill in any gaps.

Interviewer Relates His Understanding of Accident

4. The interviewer should then relate his understanding of the accident to the injured person or eyewitness. Through this review process there will be ample opportunity to correct any misunderstanding that may have occurred and clarify, if necessary, any of the details of the accident.

5. Discuss methods of preventing recurrence. Ask the individual for suggestions aimed at eliminating or reducing the impact of the hazards which caused the accident to happen. By asking the individual for his ideas and discussing them with him, the interviewer will show sincerity and place emphasis on the fact-finding purpose of the investigation, as it was explained at the beginning of the interview.

The following is an example of how *not* to conduct an interview.

Instructor Note:
Instructor has participants read incorrect method and give their reactions.

Investigator: O.K., Bill, tell me how you cut your hand. Start as far back as you can remember. I have to write it all down.

Bill: Well, it was like this. I had to rip a 4' x 8' (1.2 m. x 2.4 m.) sheet of plywood on the table saw, and I knew the guard would be in the way. So I . . .

Investigator: You took it off!

Bill: Well, yeah, I did but . . .

Investigator: You know you were told never to remove the guard. If you listened, you wouldn't have been hurt.

Bill: Yes, I know, but I didn't have much choice—

Investigator: That's what they all say. Haven't you heard enough from your instructor about never using the saw without the guard in position?

Bill (pensive look—doesn't answer)

Investigator: See what happens when you don't listen! Well, all right, be more careful in the future and follow directions. Safety is important. Do you understand that?

Bill (nods grimly)

Investigator: O.K., go back to class now and remember to be more careful and listen to your instructor or you'll be in trouble again soon.

How do you think that Bill felt at the end of this interrogation? Do you think that Bill will think twice about reporting a minor injury again? The investigator's first shortcoming was that he acted and sounded as if he was disgusted because he had to make out a report. He put the student on the defensive right at the start. He interrupted and didn't let the student finish. He was impersonal and abrupt. At no time did he express sympathy or concern for the student's injury. He even terminated the interview on a sour note. To top it all off, he never acquired a complete understanding of the accident.

Instructor Note:

Instructor has participants read correct method and give reactions.

The following illustrates the correct method of conducting an interview.

Investigator: How's your hand, Bill? Does it still hurt? Did you get proper care from the school nurse?

Bill: Yes, sir, thank you. She did a good job. The cut wasn't too deep, and it should heal O.K.

Investigator: Well, Bill, I would like to take a little of your time to go over what happened. Before you tell me, I'd like to tell you why I think it is important to check out every injury occurring in our school. Quite simply, by going over accidents carefully, often a lot can be learned to prevent similar accidents in the future. Please don't take the questions I'm about to ask personally, and don't worry about admitting that you did something wrong. I'm not trying to blame anyone. What I learn from you may prevent another student from being injured in the future.

Bill: I understand, and I'll do my best to help.

Investigator: O.K., let's go over to where you were when the accident occurred. (They arrive at the table saw area in the shop.) Bill, will you explain what you were doing and how you were doing it when the accident happened? Take your time, and try to remember as many things as you can which occureed just before the accident.

Bill: I had to rip a 4' x 8' (1.2 m. x 2.4 m.) sheet of 1/2" (1.3 cm.) plywood. Since the portable circular saw was broken, I had to either cut it by hand or use the table saw. Of course I knew that the saw guard would be in the way so I removed it and made the cut with no problem.

Investigator: Well, then, how did you cut your hand?

Bill: I know it sounds dumb, but when I was placing the guard back on the saw, I leaned over to make sure it was aligned correctly. As I did, I slipped on something and pushed my hand onto the blade.

Investigator: Was there sawdust, oil or anything else on the floor in the area of the saw? — like this sawdust (pointing to the floor)?

Bill: There probably was. Some guys never clean up after finishing their work.

Investigator: Well, Bill, let me see if I have a clear picture of this. You didn't cut your hand while the saw was running. You did it while installing the guard that you removed to get your job done. While you were installing it, you slipped and jammed your hand against the blade.

Bill: Well, not when I was putting it on—when I was making the final alignment.

Investigator: O.K. Bill, how do you think this accident could have been prevented?

Bill: If the portable saw had been available, I probably wouldn't have got hurt.

Investigator: We'll get that saw fixed right away. What about the table saw?

Bill: I should have told my instructor and got some help. Also, if we had one of those swing-type guards I've seen, I wouldn't have had to remove the guard.

Investigator: That's a good idea. I'll recommend that the school look into purchasing one. Any suggestions about the sawdust on the floor?

Bill (smiling): I'll make sure that I sweep the area around shop equipment before I go to work. It's no big deal.

Investigator: O.K., Bill. I appreciate your cooperation and your suggestions. One thing more: the next time you need to change a standard procedure in order to get your work done, let your instructor know about it before you start.

Bill (grinning): All I can say is that I will. Thanks.

The preceding example suggests ways to conduct an interview. In this case the investigator was friendly but at the same time created an image of competence. He took the time to tell Bill what he was doing and why. He conducted his interview at the scene, not in an office far removed from where the accident occurred. He listened without interrupting, was not sarcastic and didn't appear to blame Bill for the accident. In this way he found that the apparent cause of the accident was not the real cause. He carefully and expertly guided the student into making practical suggestions for correcting the hazards. In conclusion, he was able to encourage the student to seek help without putting him on the defensive.

All accident investigations do not go as smoothly as the one in our example. However, by using the techniques offered in this unit and formulating an approach along the general guidelines offered in the second interview, an instructor or department head can conduct effective accident investigations, acquire the data needed to pinpoint the cause(s) of the accident under investigation and encourage student participation in the investigation process.

KEY POINTS FOR CONDUCTING INTERVIEWS

Interviewers should remember and follow these important guidelines:

1. Conduct interviews as soon after the accident as practical.
2. Delay interviews with the injured until he has received medical treatment, no matter how minor his injuries. If the injured feels that his best interests are being placed second to a report, he is not apt to cooperate.
3. Interview one person at a time.
4. Avoid making witnesses feel that they are informers.
5. Be diplomatic.
6. Put witnesses at ease.
7. Explain the purpose of the investigation.
8. Keep questions as simple as possible.

9. Avoid the implied answer or leading question.

10. Never ridicule a witness.

11. Give the person being interviewed the opportunity to present his version, in its entirety, without interruption.

12. Review the details of acquired information.

13. Discuss methods to prevent recurrence.

ACCIDENT REPORT FORMS

Many good report forms exist for recording the facts surrounding an accident situation. At the very least, accident reports need to contain the following:

1. identification of persons involved (name, address, age, etc.)

2. time of accident (hour, day, month)

3. place of accident (specific location in school)

4. type of injury

5. identification of all witnesses

6. severity of injury (amount of lost time, cost of injury, name of attending doctor or first aid attendant, record of treatment)

7. description of property and material damage

8. exact description of the accident

    a. a full description of the accident stating, for example, whether the person fell or was struck, and all the factors contributing to the accident

    b. identification of the machine, tool, appliance, gas, liquid or other agent which was most closely associated with the accident

    c. if a machine or vehicle was involved, identification of the specific part involved (e.g., the gears, pulley or motor)

d. a judgment about the way in which the machine, tool, etc., was unsafe

e. description of mechanical guards or other safeguards (e.g., safety goggles) which were provided

f. statement about whether the person or persons used the safeguards provided

g. description of the unsafe action which resulted in the accident (e.g., removed safety screen from pulley, did not wear goggles, etc.)

h. opinion about ways of preventing additional accidents of this type.[2]

The Industrial/Vocational Education Accident/Injury/Exposure Report Form (Figure 11, Appendix A) may be used by instructors or Shop Safety and Health Committee members to record the facts relating to an accident. The form's layout allows the user to record relevant information quickly.

RECORDING AND CLASSIFYING ACCIDENT DATA

Ultimately, the data on each accident report form must be recorded and classified in such a manner that important relationships may be drawn and decisions made by members of the safety and health committees concerning accident reduction. The Shop Safety and Health Committee Accident Record Form (Table 5, Appendix B) may prove helpful in recording and presenting accident information.

Before each meeting of the Shop Safety and Health Committee, the chairman sees to it that all accidents are summarized on the record form so that they can be reviewed by the entire committee. Copies of the complete report should also be available for the committee's use.

Relevant Items on Accident Record Form

Among the facts important in a summary are the following:

1. *Case number*—the number assigned to each report for future identification and recall (e.g., 79-1)
2. *Name of injured person*
3. *Date of injury*

4. *Where accident happened*—specific place/area where accident occured (e.g., machine shop/lathe area)

5. *Nature of injury*—type of physical injury (e.g., cut, abrasion, chemical burn)

6. *Body part*—the part of body injured (e.g., left thigh, lower ribs)

7. *Source of injury*—the object, substance, exposure or bodily motion which directly produced the injury (e.g., saw blade, abrasive wheel)

8. *Tools, equipment used*—the tools, equipment or machines used when the accident occurred (e.g., metal lathe)

9. *Time lost*—the actual number of days and hours lost as a result of the accident

10. *Hazardous condition*—the condition which directly caused the accident (e.g., improperly guarded saw, oil spot on floor)

11. *Human errors*—the act of commission or omission which directly caused the accident (e.g., operating without authority, horseplay; operating at unsafe speed; misreading instruments; failing to follow instructions)

12. *Instructor/supervisor*—person who was supervising student/staff/faculty member at time of accident

13. *Costs:*

    a. *medical* (doctor and hospital costs associated with the injury)

    b. *other* (noninsured costs such as administrative time, investigation time, additional training, compensation costs).

It will be the duty of the Shop Safety and Health Committee to review the accident record forms, to recommend action and improvements to prevent similar accidents from occurring in the future, and to see if general patterns emerge which may point to previously undetected hazards or weaknesses in the health and safety program.

Instructor Note:
Instructor has participants fill out Accident Record Form (Table 5) based on the accident interview described earlier in this unit.

NOTES:

1. Adapted from "Evaluation and Control of Workplace Accident Potential," NIOSH (January 1978), XIV, 14–15.

2. Adapted from "Evaluation and Control . . .," XIV, 15–17.

QUESTIONS AND ANSWERS

1. There are four important reasons for investigating accidents in the school shop. Name them.

a. to find out what caused the accident

b. to provide information for preventing similar accidents from occurring

c. to document facts for possible compensation and litigation

d. to uncover problems which indirectly contributed to the accident.

2. Why should minor accidents receive the same attention as the major ones?

Serious accidents arise from the same hazards as minor incidents. It is usually sheer luck which determines whether a hazardous situation results in a minor incident or a serious accident.

3. Who should investigate accidents? Why?

Instructors should take a prominent role in accident investigation. They are on the scene, they are most aware of the student, machine and environmental relationships, and they have a personal and professional interest in shop safety. Shop safety and health committees should also become directly involved with serious accidents. Their involvement provides additional expertise to complement the specific knowledge of instructors.

……

4. What is the most important thing to do before beginning an accident interview?

……

Establish rapport with the person being interviewed.

……

5. What are the five steps in conducting an interview?

……

a. Discuss the purpose of the investigation and the interview.

b. Have the individual relate his version of the complete accident with minimal interruption.

c. Ask questions to clarify facts or fill in gaps.

d. Relate your understanding of the accident (as the interviewer).

e. Discuss methods of preventing recurrence.

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APPENDIX A

INDUSTRIAL/VOCATIONAL EDUCATION ACCIDENT/INJURY/EXPOSURE REPORT

INDUSTRIAL/VOCATIONAL EDUCATION ACCIDENT/INJURY/EXPOSURE REPORT

Case/Report/File No. ____________________

Name of Injured ____________________

Personnel Classification: Student ( ) Instructor ( )
Maintenance ( ) Other ( ) Specify ________

ACCIDENT DESCRIPTION

Date of Accident ____________________
Time of Accident (24 hour clock) ____________________
Accident Type (Non-Vehicular)

- Struck against . . . . ( )
- Struck by. . . . . ( )
- Fell. . . . . ( )
- Slipped/Tripped . . . . ( )
- Caught in, under, between. . . . . ( )
- Rubbed or abraded . . . . ( )
- Overexerted . . . . ( )
- Contacted (electrical, solvent, acid, etc.) . . . . ( )
- Exposed to. . . . . ( )
  - Source known/Specific. . . . . ( )
  - Source unknown/Nonspecific . . . . ( )
  - (COMPLETE "EXPOSURE EFFECTS")

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EXPOSURE EFFECTS

Dizziness, loss of balance . . . . ( )
Fainting, loss of consciousness . . . . ( )
Coughing, difficult breathing; sneezing . . . . ( )
Rash, skin irritation . . . . ( )
Other ____________________ ( )
Complaint of:

- Headache. . . . . ( )
- Loss of memory . . . . ( )
- Pain, discomfort . . . . ( )
- Sore throat. . . . . ( )
- Other ( )
- Chill/Cold . . . . ( )
- Disorientation. . . . . ( )

Source of accident (example: metal lathe) ____________________
____

School Name: ____________________

Shop Where Accident Occurred: ____________________

Supervisor in Charge of Injured: ____________________

DESCRIPTION OF INJURED (all that apply):

Age/Birth Date of Injured ____________________
Sex . . . . .Male ( ) Female ( )
Years Experience in Occupation (School Staff) ________yrs.
Grade Level (Student) ________
Did Student Receive Safety Training for Task. . . . . Yes ( ) No ( )
Time Since Last Safety Course____months ______Unknown ( ) NA ( )
Task Performed at Time of Accident (Required Project, Maintenance, Personal Project, etc.) ____________________
Years Experience with Tool, Machine, Etc., Involved in Accident ____________________
Certified by Inspector to Perform Task . . . . Yes ( ) No ( )
No. of Accidents in Previous 4 Years ________
Temporary Illness (example: flu) . . . . ( )
Affected by Medication or Drugs . . . . ( )
Operated According to Safe/Approved Practices . . . . . . ( )
Used Proper Equipment . . . . ( )
Used Equipment within Design Limits. . . . . ( )
Misread Instruments. . . . . ( )
Mislead by Faulty Instrument . . . . ( )
Equipment/Structure Restricted Vision . . . . ( )
Equipment/Structure Restricted Hearing . . . . ( )
Equipment/Structure Restricted Movement . . . . ( )
Working on Moving Equipment . . . . ( )
Operated without Authority . . . . ( )
Failed to Follow Emergency Procedures . . . . ( )
Appropriate PPE Used . . . . Yes ( ) No ( )
Was Injured Involved in Horseplay? . . . . Yes ( ) No ( )
Were Safety Devices Made Inoperative? . . . . Yes ( ) No ( )
Operating at Unsafe Speed . . . . Yes ( ) No ( )

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Figure 11

(Draw a line from injury to body part(s).
For multiple injuries, draw multiple lines.)

NATURE OF INJURY

- Sprain
- Strain
- Contusion/Bruise
- Abrasion
- Laceration
- Puncture
- Burns (Heat/Flame/Chemical)
- Fracture
- Bites/Stings
- Chest Pains
- Respiratory
- Amputation
- Foreign body in eye
- Electrical shock

BODY PART(S)

- Head
- Eye
- Face
- Ear
- Neck
- Shoulder
- Chest
- Lungs
- Abdomen
- Back
- Buttocks
- Groin
- Upper arm
- Elbow
- Forearm
- Wrist
- Hand
- Finger
- Thigh
- Lower leg
- Ankle
- Foot
- Toe
- Knee
- Other

Unknown; collapsed or unconscious . . . . ( )

Recurrence/Aggravation of previous injury . . . . Yes ( ) No ( )

Illness, if diagnosed (describe ____________________________________

____

Fatality . . . . Yes ( ) No ( )

ENVIRONMENTAL DESCRIPTION (all that apply)

Illumination/Lighting Sufficient . . . . Yes ( ) No ( )

Ventilation Sufficient . . . . Yes ( ) No ( )

Chemicals (if known, describe)

Fumes ____________________________________ ( )

Vapors ____________________________________ ( )

Mists ____________________________________ ( )

Smoke ____________________________________ ( )

Dusts ____________________________________ ( )

Static Electricity . . . . ( )

SITUATION DESCRIPTION (all that apply):

Characteristics of Immediate Supervisor

No. of Students/Employees Supervised ____________

Did Supervisor Observe Accident? Yes ( ) No ( )

No. Years Experience as Supervisor ______ yrs.

Tools and Equipment (if used at time of injury):

DESCRIPTION	MANUFACTURER	APPROX. AGE	PART OR COMPONENT FAILURE (if yes, name)
			Yes ( ) No ( ) ____________________
			Yes ( ) No ( ) ____________________
			Yes ( ) No ( ) ____________________

Safeguards or Failsafe Devices Operating . . . . Yes ( ) No ( )

Equipment Grounded. . . . . Yes ( ) No ( )

Was PPE relating to injury type and body part available? . . . . Yes ( ) No ( )

Was hazardous condition caused by:

Improper USE of materials? . . . . Yes ( ) No ( )

Improper HANDLING of materials? . . . . Yes ( ) No ( )

Improper STORAGE of materials? . . . . Yes ( ) No ( )

Personal Protective Equipment (PPE) if associated with injury:

ARTICLE	MANUFACTURER	DESCRIPTION	APPROX. AGE	PART OR COMPONENT FAILURE (if yes, name)

NON-OSHA RULES/REGULATIONS APPLYING TO ACCIDENT

AUTHORITY/SOURCE	CODE NO./ REFERENCE	PERTAINS TO
School ( )		
Shop ( )		
State (includes State-OSHA) ( )		
Other ________________ ( )		

VEHICULAR ACCIDENT SUBSET

Manufacturer/Make of Vehicle ______________________

Model/Type ______________________

Year of Manufacture ____________

Ownership/Agency ______________________

Individual Ownership ______________________

Injured was . . . Driver ( )
Passenger ( )

ACCIDENT DESCRIPTION (Vehicular only)

Contact with another moving vehicle
- In opposite direction . . . . ( )
- In same direction. . . . . ( )
- At intersection . . . . ( )

Contact with a standing vehicle or stationary object
- In roadway. . . . . ( )
- At side of road . . . . ( )

Struck by another vehicle while standing in roadway . . . . ( )

Struck by another vehicle while standing off roadway . . . . ( )

Non-collision accidents
- Overturned. . . . . ( )
- Ran off roadway . . . . ( )
- Sudden stop/start (throwing occupants out of or against parts of the vehicle or throwing contents of vehicle against injured) . . . . ( )

Point of impact ______________________

OCCUPANT DESCRIPTION (all that apply):

Operating On/Off Road . . . . On ( ) Off ( )

Safety Equipment Used . . . . Yes ( ) No ( )

Years Driving Experience ____ yrs.

Prior Experience with Vehicle Type . . . . Yes ( ) No ( )

SITUATIONAL DESCRIPTION (Vehicular only)

Estimated Speed of Travel __________ MPH

Speed Limit ______________ MPH

Vehicle Mileage ______________

ENVIRONMENTAL DESCRIPTION (Vehicular only)

Type of Surface	Surface Condition	Road Configuration (if applicable)
Concrete . . . . . ( )	Dry. . . . . ( )	Straight . . . . . . ( )
Macadam . . . . . ( )	Ice . . . . ( )	Curve . . . . ( )
Brick. . . . . ( )	Wet. . . . . ( )	Bank. . . . . ( )
Loose Gravel . . ( )	Snow/Slush . . . ( )	Curve and Bank. ( )
Dirt . . . . ( )	Mud . . . . ( )	Intersection . . . ( )
Other . . . . ( )	Other . . . . ( )	Other . . . . ( )

IDENTIFIERS (all that apply):

Social Security No. ____
Home address of Injured ____
Name of Parent/Guardian ____
Address of Parent/Guardian ____
____ Tel. Number ____

Location of accident ____
Was accident on school premises? . . . . Yes ( ) No ( )

Name of attending physician ____
Address of physician ____
Name of hospital ____
Address of hospital ____

DISPOSITION OF CASE (all that apply)

Work/School Days Lost ____
Work/Classroom Restriction ____
____
Termination/Retired . . . . ( )

Disablement, Type
- Temporary, partial. . . . . ( )
- Temporary, total. . . . . ( )
- Permanent, partial . . . . ( )
- Permanent, total . . . . ( )

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Witnesses:

Name	Address	Tel. No.

Description of Property Damage ____
____
____

Recommendations to Prevent Similar Accidents ____
____
____
____

Certified by Injured:

I have examined this report and certify that it accurately represents the facts associated with this case.

____
Signature (first and last name)

____
Date

Report prepared by ____
Official position ____
Date ____

Verified by School Administration:

____ Name
____ Title

____
Date

Workers Compensation Cost:

Indemnity ____

Medical: ____

APPENDIX B

SHOP SAFETY AND HEALTH COMMITTEE ACCIDENT RECORD FORM

TABLE 5

SHOP SAFETY AND HEALTH COMMITTEE ACCIDENT RECORD FORM

Period From ____________

To ____________

Page 1 of ______

School: ______________________________
Name
____
Address

Case No.	Name Injured Person	Date of Injury	Where Accident Happened	Nature of Injury	Part of Body	Source of Injury	Tools/ Equipment Used	Time Lost	Hazardous Condition	Human Error	Instructor/ Supervisor	Costs A Comp	B Medical	C Other
79-1	William Smith	9/8/79	Wood Working Shop – Table Saw Area	Laceration	Left Hand	Saw Blade	Table Saw	1/2 Day	Unguarded Saw Blade and Slippery Surface	Failure to Check with Inst. and Failure to Clean Area in Proximity of Saw	Mr. Yardley	n/c	$35.00	$100.00 (new saw guard)

UNIT 7

SAFETY AND HEALTH INSPECTION TECHNIQUES

METHODS	Lecture and Demonstration	LENGTH: 60 Minutes
PURPOSE	To provide the participant with an understanding of the inspection process and the ability to carry out an effective safety and health inspection in an industrial/vocational education setting.	
OBJECTIVES	To introduce the participant to: 1. Purposes of inspection 2. Types of inspection 3. Persons involved in inspection process 4. Techniques of safety and health inspection 5. Methods of recording and displaying information from inspections	
SPECIAL TERMS	1. Inspection 2. Efficiency 3. Effectiveness	
INSTRUCTOR MATERIALL	Lesson Plan 35 mm Slides, Projector and Screen Overhead Transparencies, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials Inspection Summary Report	

UNIT 7

SAFETY AND HEALTH INSPECTION TECHNIQUES

INTRODUCTION

During the discussion of hazard control processes in Unit 3, safety and health inspections were shown to be essential parts of the hazard control process. This unit will concentrate on how inspections are conducted and how the information is used to improve safety and health in industrial/vocational education.

DEFINITION OF INSPECTION

For our purposes, we will define "inspection" as a monitoring survey conducted in the workplace to locate and report existing and potential hazards which have the capacity to cause accidents.

PHILOSOPHY BEHIND INSPECTION

The inspection process can be approached from either a negative or a positive viewpoint:

1. faultfinding, with emphasis on criticism
2. fact-finding, with emphasis on locating potential hazards that have an adverse effect on the operation in terms of safety.

As we discussed in Unit 6, the second viewpoint, which emphasizes fact-finding instead of faultfinding, makes the most sense and is the one which should guide our efforts during inspections.

Inspections Are Essential and Mandatory

Every school shop and each of its processes and operations contains some existing or potential hazards which arise through normal working or production procedures or through changes or modification. One way of keeping abreast of hazards in the school shop is through continuous and periodic inspections of workplaces. Such inspections should be made mandatory.

PURPOSE OF INSPECTIONS

There are two valid purposes behind safety and health inspections.

Detect Hazards

1. The primary purpose of inspection is to detect potential hazards so that they can be corrected before an accident occurs. Through inspections it is possible to determine those conditions which need to be corrected or improved to bring school shop operations up to at least minimally

acceptable standards, both from safety and operational standpoints.

Offer Improvements and Corrections to Increase Efficiency and Effectiveness

2. A secondary purpose of inspection is to offer improvements and corrections to improve overall operations and increase efficiency and effectiveness.

TYPES OF INSPECTIONS

Safety and health inspections can be classified as either periodic or continuous.

Periodic Inspections

A periodic safety and health inspection is deliberate, thorough and systematic by design. Such inspections are often conducted by safety and health committees on a monthly or bi-monthly basis. The advantage of this type of inspection is that it covers all areas and allows the detection of changes in operations, equipment, etc., in time for effective countermeasures to be provided.

Continuous Inspections

Continuous or ongoing inspections should be conducted by instructors, department heads, students and maintenance personnel as part of their instructional, supervisory or maintenance responsibilities. Continuous inspection involves noting an apparent or potential hazardous condition or unsafe act and either correcting it immediately or making a report to initiate corrective action. The ultimate goal of a good safety and health inspection program is to promote vigilance on the part of each instructor and student to examine, correct if possible, and report any condition which has accident potential. This continuous shop montoring function is critical to a successful program and should become second nature to the instructor and student.

WHO SHOULD MAKE INSPECTIONS

Safety and health inspections must be conducted by several persons in the organization.

Instructor

Continuous and Daily Inspections

The instructor must make continuous inspections and be ever alert to changing conditions, operations and work methods. Some shop operations may require the instructor to make several inspections over the course of the instructional session to be certain that all safety precautions are being taken.

To be sure that there are no unsafe conditions to which students may be exposed, the instructor should make his inspections at the beginning of each day and, for certain equipment, at the beginning of each period.

Student Shop Foreman Daily Inspections

The student shop foreman will perform daily inspections at the beginning of each instructional period.

Department Head Weekly Inspections

Department heads play a key role in the shop inspection program. Each week these supervisors should make the rounds of the shops, recording unsafe conditions and practices and forwarding the information gathered to the instructor in charge and/or the Shop Safety and Health Committee if conditions warrant. When a department head makes a regular inspection, it reinforces his interest in the school safety and health program and inspires interest and cooperation in others.

Shop Safety and Health Committee Periodic Inspections

The Shop Safety and Health Committee is responsible for all formal inspections. This committee includes department heads, instructors, student shop foremen, maintenance personnel and, when applicable, a teachers' association representative. The diverse knowledge of committee members will reveal hazards which otherwise might be overlooked by persons less familiar with shop operations or by people experienced with only one type of shop environment.

Scheduling Inspections

Schedules should be established to permit the committee to accomplish a thorough inspection within the constraints of members' time and availability. The length and frequency of inspections depend on the size and layout of the school and the number of shops. Where there is new construction or installations or where there are changes in processes, operations or materials, the committee may need to make special, unscheduled inspections to be certain that safety requirements are being met.

Inspections conducted by the committee must be directed by an interested and responsible person to assure that the process does not become meaningless and routine. Those chosen to perform inspections should have special safety training and should update their skills continually to keep them current.

INSPECTION PROCEDURES

An inspection program implies the regular, systematic and continuous comparison of safety and health standards to discrepancies in the shop environment.

A safety and health inspection program requires:

1. sound knowledge of the school plant

2. knowledge of the material contained in standards, regulations and codes

3. a series of systematic inspection steps
4. a method of reporting, evaluating and using the data gathered.

Mapping the Route for Inspection

The committee must select a route which will permit it to do a thorough job, leave nothing out, avoid repeated examinations of the same item, keep walking to a minimum and avoid unnecessary interruptions. A closed loop inspection will give good results.

Using Safety and Health Checklists

Many different types of checklists are available for use in safety and health inspections, varying in length from thousands of items to only a few. Each type has its place and, properly used, can be of benefit to industrial/vocational education. Generally, the longer checklist refers to OSHA standards and can be used by the committee during its initial survey of its school to determine which standards apply to its individual situation (see Supplement). Once the committee determines which areas fit its situation, it can then construct a checklist tailored to its needs and uses.

Regardless of how complete the inspection checklist, the results of the inspection will be no better than the individuals performing the inspection. Inspectors must be realistic and use their ability, experience and intuition. A hazard observed during an inspection must be recorded even though it was not identified on the checklist. The inspection checklist must be used as an aid to the inspection process, not as an end in itself.

Be Methodical and Thorough

Merely running through a checklist does little to locate or correct problems of importance. Committee members must take their time and do a thorough job.

The committee also should plan to inspect areas where people rarely go or where people never have been injured. The inspection team should be sure to look for off-the-floor items (e.g., pipes, hoisting equipment, etc.), as well as those at ground level. It is better for the inspection to be incomplete but thorough than complete and superficial.

WHAT SHOULD BE INSPECTED

When planning the inspection program, the committee should consider the following areas:

Materials and Substances

1. *Materials and substances* used in education should be viewed with respect to their capacity to cause an injury, occupational illness, fire or other hazard.

2. *Machinery, equipment, tools, etc.*, used during shop operations must be free from material defects and other hazards. Particular attention should be given to machinery and the points of operation, including all moving parts as well as accessories (flywheels, gears, shafts, pulleys, key ways, belts, couplings, sprockets, chains, controls, lighting, brakes, exhaust systems, grounding).	Machinery, Equipment, Tools, etc.
3. *Personal protective and safety equipment* must exist where there is a reasonable probability that an injury can be prevented. These devices must be in working order and used according to the most recent instruction.	Protective and Safety Equipment
4. *Working and walking surfaces* (stairs, ladders, scaffolds, ramps, etc.) must be functionally safe, meeting existing safety standards, and they must be properly maintained.	Walking and Working Surfaces
5. Within the shop workplace, such *environmental factors* as illumination, ventilation, noise control devices, etc., must be within established standards.	Environmental Factors
6. Attention should be given to *housekeeping*, sanitation, waste disposal, material storage, and so on.	Housekeeping
7. *Medical services*, first aid facilities, and a means for transporting injured must be available at all times.	Emergency Areas
8. *Electrical equipment*, including switches, breakers, fuses, special fixtures, insulation, extensions, tools, motors, grounding, etc., must be determined to be in compliance with the regulations.	Electrical Equipment
9. *Chemical storage, handling, use and transportation* must be viewed with respect to adequate exhaust systems, warning signs, protective clothing and other allied equipment.	Chemicals
10. *Fire protection* and extinguishing systems, such as alarms, sprinklers, fire doors, exit signs, extinguishers, etc., deserve particular scrutiny including review of school egress plans for emergency exit.	Fire Protection
11. The regularity and effectiveness of the *preventive maintenance* program need to be assessed.	Preventive Maintenance

Dealing with Hazardous Equipment

If the committee finds a hazardous machine, piece of equipment or operation producing a health hazard, it should:

1. Warn the instructor or whoever is in charge of the condition.
2. Shut down the machine or equipment, if necessary. Tag it immediately; a lock-out along with the tag will prevent its use.

If the hazard represents an immediate danger, the instructor should be authorized and directed to take immediate action.

ASSESSING HEALTH HAZARDS

As previously stated, a thorough inspection requires that emphasis be given to both safety and health hazards. In order to be able to recognize health hazards during an inspection process, committee members need a knowledge and understanding of the environmental factors in the shop workplace which have the capacity to impair the health of students and instructors.

Later units on health hazards and hazardous materials will provide the committee with information it needs to evaluate health hazards and to perform the tasks described in the guidelines below. The committee must consider:

1. the nature of the product being produced
2. the raw materials being used
3. materials and substances being added in the process
4. by-products produced
5. the equipment involved
6. the cycle of operations
7. operational procedures being used
8. health and safety controls utilized
9. number of persons exposed and level of exposure to harmful chemical, biological and physical agents.

Guidelines for Health Hazard Inspections

As it inspects the shop for health hazards, the Shop Safety and Health Committee may want to use the following guidelines:

1. List all hazardous chemical, physical, and biological agents in the school.
2. Determine where the hazardous health agents are in the school and the state in which they exist (e.g., dust, fumes, mists, vapors, smokes, gases).
3. Determine the threshold limit value for all chemical, physical and biological agents, and compare against actual levels in the shop workplaces.
4. Determine which processes and equipment are capable of producing hazardous levels during operations.

RECORDING HAZARD FACTS

The Shop Safety and Health Committee should take precautions to locate and describe each hazard found during inspection. As hazards are uncovered, a clear description of the hazard should be written down and a committee member should record all questions and details for later use.

Classifying Hazards

During the inspection it is important to determine which hazards present the most serious consequences and are most likely to occur. The hazard ranking scheme discussed in Unit 3 will make the job of classifying hazards an easy one. Classifying hazards properly places them in the right perspective, assigns priorities and aids in correcting the condition ultimately preventing accidents.

Another significant benefit of classifying hazards is that it describes the potential loss severity and probability without the need for long narrative descriptions. It helps the school administrator or the Safety and Health Policy Committee to understand and evaluate the problems found and reach decisions quickly.

The inspection Summary Report (Table 6) is designed to assist the individual inspector to record pertinent facts relating to a safety and health inspection.

SUMMARIZING INSPECTION DATA

Upon completing the inspection, the committee members should assemble and combine their separate findings into a single inspection summary report, which will include recommendations for corrective action.

USING THE DATA ACQUIRED DURING INSPECTIONS

What is done with the information acquired from an inspection program is as important as the inspection process itself. It is necessary that the inspection team bring problems and recommendations for corrective action to the attention of the Safety and Health Policy Committee or the principal.

General Recommendations for Improvements

General recommendations could include:

1. Change the procedure. Set up a better process, operation or work task.
2. Limit the exposure. Relocate the present process in such a way as to make it less hazardous while at the same time providing better results.
3. Redesign a tool or fixture or change the students' work pattern to reduce the hazard potential.
4. Give more adequate training to personnel engaged in a particular operation.
5. Provide personal protective equipment.[1]

Based on the problems uncovered and recommendations made by the Shop Safety and Health Committee, the Policy Committee or the school administrator must decide what course of action to take. Usually these actions will be based on the cost effectiveness of the recommendations. For example, it may be effective and practical, from a cost standpoint, to substitute a less toxic material that works as well as the highly toxic material presently in use. On the other hand, a particular hazardous machine may be too costly to replace. In this case, the choice may be the less expensive alternative of installing machine guards to correct the problem.

SUMMARY

Instructor Note:

At this point the instructor should refer to the Appendix for directions concerning the use of the inspection Summary Report Form.

Information from inspections should never be used for punitive action. The information should be viewed as the basis for establishing priorities and implementing programs that will reduce accidents, improve conditions, raise morale and increase the overall effectiveness of the school organization.

NOTES

1. Adapted from Robert J. Firenze, *Guide to Occupational Safety and Health Management* (Dubuque: Kendall/Hunt, 1973), p. 90.

QUESTIONS AND ANSWERS

1. Give a definition of safety and health inspection.

An inspection is a monitoring survey conducted in the workplace to locate and report existing and potential hazards which have the capacity to cause accidents.

2. The inspection process can be conducted from two different and opposing viewpoints. Name each.

a. faultfinding, with emphasis on criticism

b. fact-finding, with emphasis on locating potential hazards that have an adverse effect on the operation in terms of safety.

3. Name two purposes of inspection.

a. to detect hazards so that they can be corrected before an accident occurs.

b. to offer improvements and corrections to increase efficiency and effectiveness.

4. Differentiate between the two main types of inspections and the people who perform each type.

a. periodic—a systematic, deliberate, thorough inspection covering all areas. Usually performed by the Shop Safety and Health Committee monthly or bi-monthly, though the department head's weekly inspection also might fall in this category.

b. continuous—an ongoing process which involves noting apparent or potential hazardous conditions or unsafe acts and either correcting them immediately or initiating corrective action. Performed on a daily basis by instructors and students and by department heads and maintenance personnel when they are in the area.

……

5. Name five areas to be considered in a thorough safety inspection.

……

Any five from among the following:

a. materials and substances

b. machinery, equipment, tools, etc.

c. personal protective and safety equipment

d. working and walking surfaces

e. environmental factors

f. housekeeping

g. medical services

h. electrical equipment

i. chemicals

j. fire protection

k. preventive maintenance

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U.S. Department of Labor, Occupational Safety and Health Administration, *Safety and Health Inspections for an Effective Safety and Health Program*, February 1977.

APPENDIX

INSPECTOR SUMMARY REPORT

Instructor Note: *Using the Inspection Summary Report* — At the point indicated in the unit, the instructor distributes Inspection Summary Report forms (Table 6) to the participants. He then shows a series of slides taken in a variety of industrial/vocational education shops. Participants are instructed to record, on their report forms, the hazards they find.

When the exercise is completed, the instructor shows each slide again. The participants are invited to offer their views of existing and potential hazards found.

TABLE 6

Date of Inspection: ____________

School: ____________

Committee Members:

Building: ____________

SHOP SAFETY AND HEALTH COMMITTEE
INSPECTION SUMMARY REPORT

No.	Description of Hazardous Condition	Specific Location	Supervisor	Hazard Rating		Priority	Corrective Action	Hazard Corrected Date
				Conseq.	Prob.			
1	Pulley Belts Exposed on Shaper and Horizontal Milling Machines	Machine Shop	William Dixon	III	A	I	Provide Sheet Metal Guards on All Machinery with Exposed Belts	

UNIT 8

PRINCIPLES OF GOOD SHOP PLANNING

METHODS	Lecture and Demonstration LENGTH: 45 Minutes
PURPOSE	To discuss the basic considerations in the layout and design of industrial/ vocational education shops.
OBJECTIVES	To introduce the participant to: 1. Basic considerations in shop layout 2. Such design considerations as materials storage, personal service facilities, exhaust, ventilation, and fire extinguisher systems, electrical requirements and illumination 3. Placement of machinery 4. Criteria for purchasing machinery.
SPECIAL TERMS	1. General Dilution Systems 2. Local Exhaust Systems 3. Single-Dimension, Two-Dimensional and Three-Dimensional Methods
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Chalk Board/Chalk
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials

UNIT 8

PRINCIPLES OF GOOD SHOP PLANNING

INTRODUCTION

Role of Instructor in Planning

One of the primary resources used in planning the layout and arrangement of a school shop should be the industrial/vocational education instructor. His knowledge and experience are of exceptional value to school administrators and architects in planning new school shops or altering or expanding old ones. The instructor's knowledge of how operations take place and what is needed complements the architect's knowledge of how feasible are the various design and construction alternatives. Together, they can reduce, if not eliminate, many of the problems that are encountered in shop construction and expansion.

Accidents Can Be Prevented or Minimized

This marriage of knowledge, experience and imagination will prove most fertile if the instructor and architect give high priority to safety and health needs while planning the layout and arrangement of the school shop. Numerous accidents, occupational illnesses, explosions and fires can be prevented or minimized if suitable measures are taken early in the planning stage.

Purpose of Unit

Shop Layout
Design Aspects
Placement of Machinery
Purchase of Machinery

The purpose of this unit is not to provide a complete guide to shop planning. Rather, we will discuss some basic considerations in shop layout, such design aspects as providing materials storage, personal service facilities, adequate illumination, electrical requirements, exhaust, ventilation and fire extinguisher systems, placement of machinery and criteria for purchasing machinery.

SHOP LAYOUT

In order to avoid difficulties of organization and supervision, it is generally recommended that shop length should be no more than twice its width. A width of thirty feet (9.1 m.) is generally used. The space allotted to shop work generally should be not less than 55 square feet (5.1 square meters) per pupil. All parts of the shop should be visible to the instructor. Window space should be not less than one-fifth of the floor space, and ceiling height should be between 10½ and 14 feet (3.2 and 4.3 m.). An open assembly area should be provided where large projects can be assembled.[1]

Water, air, hydraulic, electrical and other piping or conduit systems should be contained in the walls to eliminate the need for constant cleaning.

Working Spaces

Floors, ramps, stairs, ladders and scaffolds deserve special consideration in shop design and are discussed in the next unit, Safe Working Surfaces. Floor materials should be easy to clean and as slip-resistant as possible. Safe load limits must be considered along with the total weight burden. Because floors begin to sag when overloaded, it is important to know the weight capacity of floors before installing equipment or machinery or storing heavy materials. To be safe, floors should have weight capacities four times the static load or six times the moving load.

Aisles

A general rule is that main aisles should parallel the flow of materials in process. Main aisles should be four feet (1.2 m.) wide. Aisle spaces should be kept clear at all times of material or equipment. The edges of all aisles should be identified by painting a clearly visible white or yellow line on the floor. Tool rooms and emergency equipment should be located off the main aisles.

Exits

Exits should be sufficient both in number and size and located so that, in case of fire or other emergency, the building could be quickly evacuated without loss of life. Plans should be adequate and conform to OSHA standards, National Fire Protection Association (NFPA) Building Exits Code, and to state and local requirements. Changing or adding exits after a building has been constructed is very costly.

To a large extent, the number and width of exits are determined by the building occupancy. In high hazard occupancy, no person should be more than 75 feet (22.9 m.) from an exit. For medium and low hazard, 100 to 150 feet (30.5 to 45.8 meters) is permissible. NFPA Standard No. 101 specifies that access to exits provided by aisles, passageways, or corridors should be convenient to every occupant and that the aggregate width of passageways and aisles should at least equal the required width of the exit.[2]

All shops should have at least two exits, one of which should be wide enough to permit moving large equipment in and out.

Exit doors should be clearly visible, illuminated, provided with signs, and open in the direction of exit travel. They should not be locked or blocked by machinery or equipment. Exits should be located where they will not be eliminated by any future addition to the building.

DESIGNING FOR SPECIFIC SAFETY NEEDS

Planners must realize that efficient shop management depends, to a large extent, on the availability of and access to tools and mate-

Storage of Materials

rials. In addition, sufficient project storage areas are necessary to avoid confusion, theft, damaged projects and general discontent among the student population. Consideration should be given as to what type of storage area is most appropriate: closed, completely open, or a combination of both.

Storage Racks

The size of storage rooms and areas will depend upon the amount and size of stock to be kept on hand. Storage areas should be equipped with both vertical and horizontal racks. Racks should be so designed and constructed that heavy stock can be pulled out without the racks tipping. In the lumber room or area, vertical stacking has several distinct advantages:

1. Warpage is reduced.
2. Less dust collects, and the stock remains cleaner.
3. Chances of stock falling onto students and instructors are reduced.
4. Stock can be removed without requiring the assistance of others or the use of ladders.
5. Smaller pieces of stock can be removed without moving larger pieces.
6. Taking inventory is easier.

Where space permits, separate racks should be used for each variety of stock.

Pieces of stock which are of irregular size do not lend themselves readily to storage in a rack. They should be stored on flat shelves beneath work benches.

In the industrial/vocational education shop there are many small parts such as nuts, bolts, washers, rivets, etc. Therefore, the installation of bins, drawers, cabinets with drawers or similar storage spaces is absolutely essential.

We will examine in a later unit the special storage requirements of such flammable liquids as thinners, solvents, finishing materials, etc.

Lockers

Student lockers should be perforated for ventilation and large enough to accommodate shop clothing. It is a good idea to specify that the tops of lockers be sloped to prevent excessive build-up of dirt and accumulation of materials on top. Lockers should be fastened to the shop floor to prevent them from being overturned.

Personal Service Facilities

An area often overlooked in the design and layout of school shops is the procurement and placement of such personal service facilities as drinking fountains, wash basins and soap dispensers. Such items play an important role in maintaining student health.

Drinking Fountains

A general rule of thumb is to install drinking fountains at a convenient location within every shop, but located in an area away from machinery or operations such as welding, heat-treating metals, and so forth. Planners will be assisted by specifications from the American National Standards Institute when purchasing and installing drinking fountains (ANSI C33.82, 1972).

Wash Basins

Soap Dispensers

Each shop should be equipped with a minimum of one wash basin, a two-foot (60 cm.) trough, or a circular or semi-circular wash fountain with hot and cold running water for every twenty students. A good quality soap distributed from a dispenser plays a dual role: it provides for ordinary hygiene, and it protects against dermatitis. Paper towels in covered dispensers also should be available, along with a closed disposal receptacle in close proximity to the washing facility.

Quick Drenching Facilities

Safety showers and eyewash fountains for quick drenching and/or flushing of the eyes and body must be provided within the work area when a person may be exposed to injurious corrosive materials.

Medical and First Aid Supplies

Planners must be sure that first aid supplies, approved by the American Red Cross or other authoritative source, are readily accessible. These supplies should be in sanitary containers with individually sealed packages for material such as gauze, bandages, and dressings that must be sterile. Other items often needed are adhesive tape, triangular bandages (to be used as slings), inflatable plastic splints, scissors, and mild soap for the cleansing of wounds or cuts.

Exhaust and Ventilation Systems

Control of air contaminants is a subject of pressing concern. Industrial/vocational shop practices create various dusts, gases, smokes, vapors and mists which, unless intercepted, will enter the shop atmosphere. These contaminants can produce a variety of occupational related illnesses: diseases of the lung, dermatitis, etc.

Planners must pay particular attention to the design and installation of both general and local exhaust ventilation systems. General dilution systems are designed to remove air throughout the shop atmosphere at pre-determined intervals and replace it with air that is free of contaminants. Local exhaust systems, on the other hand, are designed to prevent a contaminant from reaching the operator by capturing it near its source and carrying it away to special collectors, a point where the general ventilation system can dispose of it, or outside the building.

Exhaust and ventilation systems are most critically needed in places where solvents are used, where fumes accumulate, and where dust is produced. The subject of exhaust and ventilation systems will be treated more fully in the unit on occupational health hazards.

Vacuum Systems and Waste Removal

Planners should consider the installation of vacuum systems and special openings designed to remove or store waste to be collected and disposed of by other means.

Fire Protection

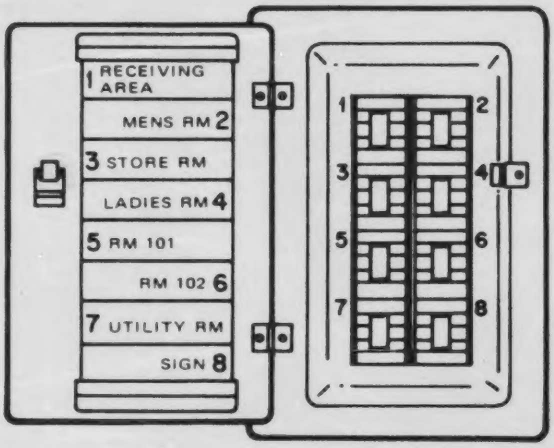
Although good shop plans will specify the provision of fire detection, alarm, and extinguishing systems, planners must supplement these systems with portable fire extinguishers, readily accessible and easy to use. Safety containers for flammable liquids, fire blankets and approved receptacles for oily rags and waste materials should be placed at critical locations. The subject of fire protection will be discussed in a later unit.

Electrical Requirements

More fires are caused by electrical malfunction than by any other cause.[3] The National Electrical Code, NFPA 70-1971, ANSI C1-1971, has been adopted as a national consensus standard by OSHA. The purpose of the NEC is the practical safeguarding of persons and buildings and their contents from hazards arising from the use of electricity. The code contains basic minimum provisions considered necessary for safety. Planners, maintenance personnel, and instructors should be familiar with these requirements and should inspect regularly for compliance:

Means for Disconnecting

1. Each means of disconnection (e.g., circuit breaker or fuse box) must be legibly marked to indicate its purpose unless its purpose is evident.



Proper labeling of circuit breakers.
Reprinted from *Health and Safety Guide—Automotive Parts Recyclers* (Cincinnati: NIOSH, 1976), p. 66.

Grounding of Motors

2. Frames of electrical motors, regardless of voltage, must be grounded.

Grounding of Noncurrent-Carrying Metal Parts

3. Exposed noncurrent-carrying metal parts of fixed equipment that may become energized under abnormal conditions must be grounded under any of the following circumstances:

    a. in wet or damp locations

    b. if in electrical contact with metal

    c. if operated in excess of 150 volts to ground

    d. in a hazardous location.

4. Exposed noncurrent-carrying metal parts of the following plug-connected equipment, which may become energized, must be grounded or double-insulated and distinctly marked:

    a. portable, hand-held, motor-operated tools

    b. appliances

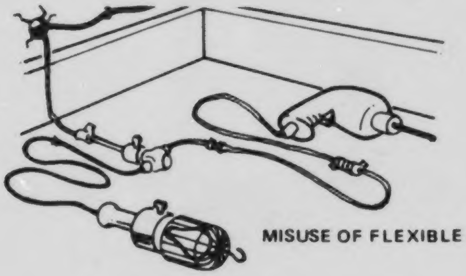
   c. any equipment operated in excess of 150 volts to ground.

Outlets, Switches, etc.

5. Outlets, switches, junction boxes, etc., must be covered.

Flexible Cords

6. Flexible cords may not be:
   a. used as a substitute for fixed wiring
   b. run through holes in walls, ceilings or floors
   c. run through doors, windows, etc.
   d. attached to building surfaces.
7. Flexible cord must be fastened so that there is no pull on joints or terminal screws. It must be replaced when frayed or when the insulation has deteriorated.



MISUSE OF FLEXIBLE CORDS

Reprinted from *Health and Safety Guide—Automotive Parts Recyclers* (Cincinnati: NIOSH, 1967), p. 67.

8. All splices in electrical cord must be brazed, welded or soldered or join the conductors with suitable splicing devices. Any splices, joints, or the free ends of conductors must be properly insulated.[4]

Illumination

The shop planner must consider the quantity and quality of illumination required for various tasks, the problem of glare and the placement of specialized lighting equipment in hazardous areas. The topic of illumination will be examined in greater detail in Unit 11, Illumination and Color.

PLACEMENT OF MACHINERY

Regardless of the type of shop planned, the design and arrangement of equipment, machinery, tools and materials should be engineered for the most effective and efficient hazard controlled operations. Consideration should be given to:

- the flow of materials
- placing machines adjacent to ones needed for successive operations
- providing sufficient space so that students do not interfere with each other
- preventing interference between operations and operator
- determining the maximum amount of space needed for machines used with large pieces of stock
- placing machines near materials
- allowing space for hand trucks
- allowing space for cleaning and maintenance.

Flow of Materials

Because the manner by which materials are brought into and are handled in the shop can produce hazards, materials flow must be a major concern in planning. The planner should trace the route the materials travel in the shop, from the time they are received through the various stages of transportation and storage and the final stage of completion and disposal. Tracing the route of materials and analyzing each operation and movement of materials from the standpoint of hazards is consistent with the theory of Shop Operations Hazard Analysis discussed in Unit 4. After analysis is complete, suggestions can be made to control or eliminate the hazards discussed.

Related Machinery Adjacent

If operations require the student to move from one machine to another for successive operations, the machines should be located adjacent to or as close to each other as possible to shorten the distance the student must travel. Reducing the need for criss-crossing and backtracking helps to lessen the danger of collision and needless exposure to potential hazards from other equipment.

No Interference Between Students

Enough space should be provided between machines to prevent the students from getting in each other's way, while permitting the instructor to provide the necessary training and supervision. In specialized shops, the space requirements range from as little as

30 square feet (9.1 m.) per student (for drafting) to as much as 100 square feet (30.5 m.) per student (for the machine or auto mechanics shop).[5]

No Interference Between Operations and Operator

Special care must be taken to locate equipment in such a way that there is no interference between the operations and the operators. When feasible, machines should be placed at a 45° angle to window walls in order to ensure that the shop receives the maximum amount of natural light. Placing the machines at a 45° angle also ensures that operators will be out of alignment with the moving parts of adjacent machines, thereby reducing the danger from machine accessories or materials which may be thrown from neighboring equipment.

Determine Maximum Space Need

The largest piece of material each machine can handle should be determined, since additional space may be needed. A lathe to be used for machining long bars fed through the head stock obviously needs more space to the left of the machine than one which is to be used only for chuck work. Certain machines, such as the metal working planer and shaper, need to be placed so that sufficient clear space remains when tables or rams are operating at their maximum distances. Other machines, such as cutoff saws and shears, should be placed near the materials storage areas in order to reduce hazards from handling large pieces of stock.

Placement of Heavy Machinery

Heavy-duty machinery and equipment should be placed as close as possible to the entrance through which heavy material is received. Consideration also should be given to the feasibility of installing electric hoisting devices. All heavy equipment should be leveled and securely fastened to floors. The placement of felt, cork, rubber, or other shock-absorbing materials under machines is recommended in order to reduce vibration and noise.

Space for Hand Trucks

When deciding where to place machinery, planners should allow space for hand trucks to be brought as close as possible to unload jigs, boxes of materials, and so forth.

Space for Cleaning and Maintenance

Machinery should be located so that there is sufficient room for cleaning, maintenance and repair work.

Using Scaled Drawings of Floor Plans

Methods used in placement of equipment usually involve scaled drawings of floor plans indicating fixed obstructions, such as supporting pillars in walls, windows and door openings, and the relationship of the room to other service areas. The "single dimension method" involves showing the relative location of all equipment and facilities on a drawing. The "two-dimensional method" is more frequently used and involves arranging flat patterns on the floor plan drawing. The patterns are to scale and in the shape of the floor area required for each item of equipment. A more revealing technique is to set up three-dimensional scale models of equipment on a drawn-to-scale plan. Some equipment manufacturers furnish models upon request, and other models can be carved from soft wood or made from cardboard.

The planner should make several layouts before deciding which will be implemented. The introduction of a single item of equipment may demand the rearrangement of the entire floor plan.[6]

CRITERIA FOR PURCHASING MACHINERY

The time spent establishing the criteria for the purchase of machinery for the shop will be well spent, and many problems will be eliminated or at least reduced. Among the criteria for selecting shop machinery are the following.

Automatic Lubrication

1. Provisions must exist for the automatic lubrication of critical parts and for effective collection systems.

Easy Access to Parts

2. Machine parts subject to wear and/or needing periodic adjustments or lubrication should be easily accessible.

Automatic Feeds and Waste Removal

3. Automatic feeds and systems for waste removal should be present. Dust collectors on machinery reduce the amount of airborne particulate matter.

Removal of Atmospheric Contaminants

4. Provisions must be made for the continual removal of metal particles, fumes, mists, gases and vapors during the operation of the machinery.

Reduction of Noise and Vibration

5. Provisions should be made for reducing noise and vibration through enclosures, shock mountings, and other attenuation and dampening techniques.

Easy Access to Electrical Switches

6. Electrical on-off switches should be located within easy reach of operators.

Emergency Stop Buttons

7. Emergency stop buttons and main power disconnect should be provided.

Color Coded Operating Controls

8. Operating controls should be color coded according to standards.

Protected Operating Levers

9. Operating levers should be protected to prevent accidental starts.

Placement of Machine Controls

10. Machine controls should be located in a manner that students will not be required to be in close proximity to the point of operation while activating the controls.

Guards

11. Guards should be provided at all points of operation as specified by the manufacturer and OSHA regulations.

12. Ideally it should be impossible to start the machine unless guards are in place and access doors are closed and latched.

Protected Power Transmission Components

13. Power transmission components such as belts and pulleys should be protected to prevent contact with moving parts.

Overload Devices

14. Overload devices should be built into the machine.

Grounded Electrical Equipment

15. All electrical equipment, especially hand-held equipment, should have an effective grounding system.

16. Adequate illumination should be provided for all points of operation.

17. Wherever possible, all sharp corners and edges should be rounded.

Because of highly competitive marketing, some manufacturers of machine tools find it advantageous to list safety devices designed for the protection of operators as auxiliary equipment. School shop personnel must be familiar with such items and make sure that they are included in the original purchase order.

Machine Guarding

Safeguarding the student from dangerous parts of the machinery and equipment is a primary concern in writing specifications for shop equipment. A well-guarded machine, in addition to being safe to work on, is valuable from a psychological standpoint. When a student's fear of a machine is alleviated, his concentration can be devoted to his work activities. So important is the subject of machine guarding that an entire unit will be devoted to it.

In this unit we have discussed how design, layout, and wise placement and purchase of machinery can provide a sound basi for shop safety. The subject of shop planning will be continued in the next unit, which deals with the construction and maintenance of safe walking and working surfaces.

NOTES

1. "Planning the New School Shop" in *Modern School Shop Planning* (Ann Arbor: Prakken Publications, 1967), p. 28.

2. See *Accident Prevention Manual for Industrial Operations* (Chicago: National Safety Council, 1974), p. 389.

3. Factory Mutual Engineering Corporation estimates that 22 percent of industrial fires are electrical in origin. This is more than twice the number of the second leading cause (incendiarism, 10 percent). See *Accident Prevention Manual for Industrial Operations: Engineering and Technology* (Chicago: National Safety Council, 1980), p. 641.

4. *Health and Safety Guide—Automotive Parts Recyclers* (Cincinnati: NIOSH, 1976), pp. 65–67.

5. *Modern School Shop Planning*, p. 13.

6. This section on scaled drawings is adapted from Frank W. Godbey, *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), pp. 30–31.

QUESTIONS AND ANSWERS

1. The school shop must be designed with attention to several important areas. Name four.

Any four from among the following:

a. materials storage

b. personal service facilities

c. exhaust and ventilation systems

d. fire protection systems

e. electrical requirements

f. illumination.

2. What are five considerations to be kept in mind when arranging the placement of machinery?

Any five from among the following:

a. providing for the flow of materials

b. placing machines adjacent to ones needed for successive operations

c. providing sufficient space so that students do not interfere with each other

d. preventing interference between operations and operator

e. determining the maximum amount of space needed for machines used with large pieces of stock

f. placing machines near materials

g. allowing space for hand trucks

h. allowing space for cleaning and maintenance.

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U.S. Department of Labor, Bureau of Labor Standards, *Planning Layout and Arrangement for Safety*, Bulletin 289, 1967.

UNIT 9

SAFE WORKING SURFACES

METHODS	Lecture and Demonstration	LENGTH: 60 Minutes
PURPOSE	To discuss the major considerations in providing and maintaining safe working surfaces in the industrial/vocational education shop.	
OBJECTIVES	To introduce the participant to: 1. Classification of falls 2. Safety requirements for floors, ramps, railings, stairs, ladders and scaffolds.	
SPECIAL TERMS	1. Standard Railing 2. Maximum Slope 3. Maximum Rise 4. Lapping 5. Tubular Scaffold 6. Suspended Scaffold 7. Mobile Scaffold	
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials	

UNIT 9

SAFE WORKING SURFACES

INTRODUCTION

In Unit 8, in our discussion of planning layout and arrangement of the industrial/vocational education shop, safe walking and working surfaces were mentioned as an important element in the safety program. Working surfaces may be floors, ramps, stairs, ladders or scaffolds. In the school shop, as in most industrial workplaces, students' falls on or from these surfaces are a leading cause of injuries.

CLASSES OF FALLS

Generally speaking, there are two broad classifications of falls:

1. from the same level
2. from different levels.

Analyses of injuries indicate that falls from higher levels usually result in severe injuries.. However, falls on the same level occur more frequently and can result in serious injuries.

MAJOR CONSIDERATIONS IN REDUCING FALLS IN THE SHOP

There are three major areas of concern in reducing slips and falls in the shop. They are

1. selection and placement of flooring materials
2. selection of the most efficient systems for transporting people and material from one level to another; e.g., ramps, ladders, stairs, etc.
3. maintenance of working and walking surfaces.

WALKING AND WORKING SURFACES

In this unit, specific working and walking surfaces will be examined. They are:

1. floors
2. ramps
3. stairs
4. ladders
5. scaffolds.

FLOORS

Unsafe floors are a primary source of accidents in the industrial/vocational school shop. Shop floors are hazardous to students and instructors when they are not maintained in serviceable condition, when they are not kept free from materials and other obstructions, or when they are uneven or slippery. Each of these hazards will be discussed in greater detail.

Slippery Floors

Slippery floors usually result from one or more of the following situations:

1. the spilling of water or other liquids such as grease or oil. This condition can be eliminated by repairing leaks, providing spill pans and cleaning up spilled substances immediately.
2. improper draining of water, from seepage from the outside, washing, etc. This condition can be corrected by providing an adequate number of drains at the low points of floors; in severe situations, the floor may have to be resurfaced with attention to adequate slope.

Obstructions

Materials, tools and work in process often become obstructions to the uninterrupted flow of traffic in the shop. Students should be instructed not to use the shop floor as storage areas for equipment, materials and their projects. Adequate storage areas should be provided.

Uneven Floors

Among the most common causes of uneven floors in the shop are:

1. warping from water or moisture
2. loose boards
3. excessively worn surface planks
4. settling of the building
5. improper alignment of floors during the construction of additions to rooms
6. depressions, cracks or ruts caused by dragging heavy items across floors or from the wheels of materials-handling equipment. Rubber tires on equipment help to compensate for this problem.

RAMPS

Recommended Maximum Rise

1' = .3 m.
10' = 3 m.
8' = 2.4 m.
80' = 24 m.

Ramps can be the source of accidents: slipping on, sliding down, falling off; tripping on uneven surfaces; losing control of wheeled vehicles; collisions; collapse caused by excessive strain. Ramps are the simplest means of getting from one elevation to another. They can be constructed of timbers, concrete, metal or asphalt. The generally recommended maximum rise of one foot in ten feet of distance limits the use of ramps where there is need for considerable height; thus, a ramp to reach an eight-foot height would have to start 80 feet away. If the ramp is to be used by vehicles (trucks, lift trucks, etc.), it would be hazardous if it were too steep.

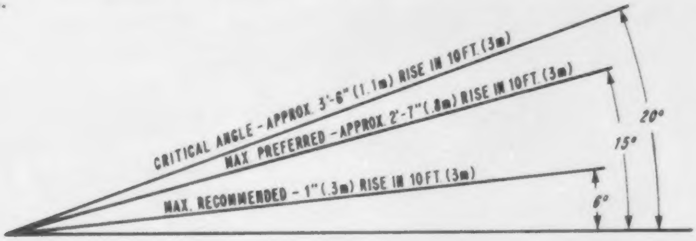
Maximum Slope

1" per foot = 2.5 cm. per 30 cm.

1-3/16" per foot = 3 cm. per 30 cm.

2" per foot = 5 cm. per 30 cm.

Ramps should have the lowest degree of slope that is practical. Six degrees is the recommended maximum slope; it should never exceed the critical angle, which is 20 degrees. According to the Building Exits Code (Vol. 4, National Fire Codes—NFPA), "All ramps used in connection with exits shall be of substantial construction, adequately designed for use as exits." Ramps in places of assembly may have the following maximum slopes, depending on the building's capacity: Class A (capacity, 1000 people or more) — one inch per foot; Class B (capacity, 200—1000) — 1-3/16 inches per foot); Class C (under 200) — two inches per foot.


CRITICAL ANGLE - APPROX. 3'-6" (1.1m) RISE IN 10FT. (3m)
MAX. PREFERRED - APPROX. 2'-7" (.8m) RISE IN 10FT. (3m)
MAX. RECOMMENDED - 1" (.3m) RISE IN 10FT. (3m)
20°
15°
6°

Reprinted from *Safe Working Surfaces,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 292 (1967), p. 5.

If ramps are to be used for wheeled traffic between levels, they should have a solid curb on open sides and, to prevent bottlenecks, should be as wide as the aisles or road they service.

Surfaces

11" to 16" = 28 to 41 cm.

The surfaces of steep ramps should be of anti-slip material, such as abrasive metal plates, non-slip compounds or abrasive paints. Cleats, when necessary for hand-trucking operations, should be evenly spaced eleven to sixteen inches apart and should not interfere with operation of trucks. Planks should not overlap and should run the long way of the ramp.

STANDARD RAILINGS AND TOEBOARDS[1]

4' = 1.2 m.
4" = 10 cm.

Standard guardrail systems are recommended especially for that part of the ramp four feet or more above adjacent floor or ground areas. Four-inch toeboards should be provided on open sides if persons can pass near or under the ramp, if the ramp is over or near machinery, or if material while being transported might create a hazard if dropped (for example, round objects).

Standard Guardrail System

42" = 1 m.
2" = 5 cm.

A standard guardrail system consists of a top rail, intermediate rail (midrail) and posts, with a vertical distance of 42 inches (plus or minus two inches) from the upper surface of the top rail to the floor, runway or platform (see Figure 13). According to OSHA requirements in 1910.23(e)(3):

2" x 4" = 5 cm. x 10 cm.
6' = 1.8 m.

1" x 4" = 2.5 cm. x 10 cm.
8' = 2.4 m.

> For wood railings, the posts shall be of at least two-inch by four-inch stock spaced not to exceed six feet; the top and intermediate rails shall be of at least two-inch by four-inch stock. If top rail is made of two right-angle pieces of one-inch by four-inch stock, posts may be spaced on eight-foot centers, with two-inch by four-inch intermediate rail.

1-1/2" = 3.8 cm.
8' = 2.4 m.

> For pipe railings, posts and top and intermediate railings shall be at least 1-1/2 inches nominal diameter with posts spaced not more than eight feet on centers.

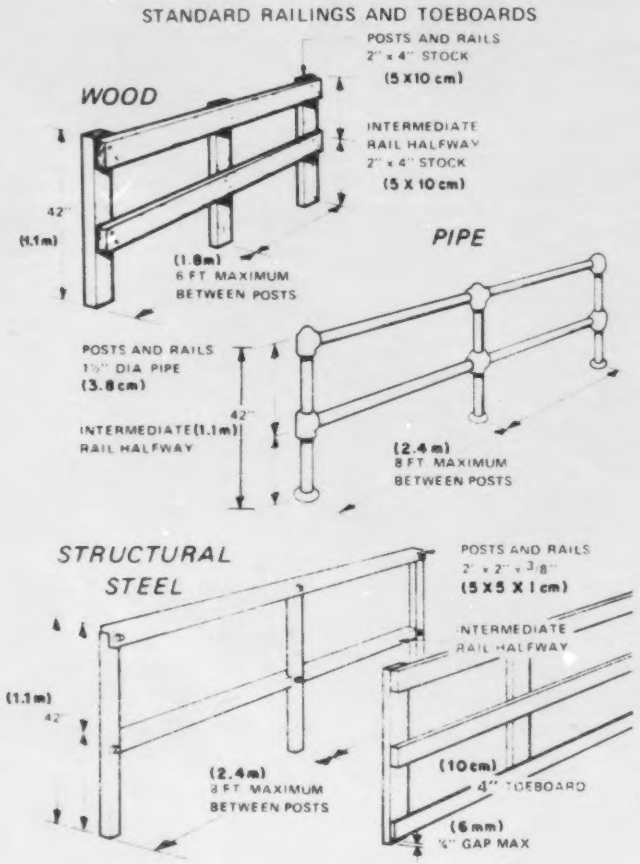
2" x 2" x 3/8" = 5 cm. x 5 cm. x 20 mm.
8' = 2.4 m.

> For structural steel railings, posts and top and intermediate rails shall be of two-inch by two-inch by 3/8-inch angles or other metal shapes of equivalent bending strength with posts spaced not more than eight feet on centers.

4" = 10 cm.

1/4" = 6 mm.

Rail frames must be anchored to platforms to withstand a thrust of 200 pounds applied in any direction at any point of the top rail. The intermediate rail (midrail) should be approximately halfway between the top rail and the floor, platform, runway or ramp. A toeboard must be at least four inches high from its top edge to the level of the floor, platform, runway or ramp. It should be made of substantial material and securely fastened in place with not more than 1/4-inch clearance above floor level.


STANDARD RAILINGS AND TOEBOARDS
WOOD
POSTS AND RAILS 2" x 4" STOCK (5 X 10 cm)
INTERMEDIATE RAIL HALFWAY 2" x 4" STOCK (5 X 10 cm)
42"
(1.1 m)
(1.8 m) 6 FT MAXIMUM BETWEEN POSTS
PIPE
POSTS AND RAILS 1½" DIA PIPE (3.8 cm)
42"
INTERMEDIATE (1.1 m) RAIL HALFWAY
(2.4 m) 8 FT MAXIMUM BETWEEN POSTS
STRUCTURAL STEEL
POSTS AND RAILS 2" x 2" x 3/8" (5 X 5 X 1 cm)
INTERMEDIATE RAIL HALFWAY
(1.1 m) 42"
(2.4 m) 8 FT MAXIMUM BETWEEN POSTS
(10 cm) 4" TOEBOARD
(6 mm) ¼" GAP MAX

From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 40.

Figure 12

In addition to their use on ramps, standard railings are required by General Industry Safety and Health Standards (OSHA 1910.23) at:

Locations Where Standard Guardrail Systems Are Required

1. every open-sided floor or platform four feet or more above the adjacent floor or ground level. These areas must be guarded on all open sides, except where there is an entrance to a ramp, stairway or fixed ladder.

4' = 1.2 m.

2. every stairway opening (on all open sides) except the entrance to the stairway.

3. every ladderway floor opening. These openings must be guarded by a standard guardrail system and towboard on all sides, with passage through the railing constructed so as to prevent a person from walking directly into the opening.

4' = 1.2 m.

4. every runway or catwalk four feet or more above ground level. These openings must have protection on all open sides.

10' = 3 m.

5. on scaffolds or platforms ten feet or more above the ground.

6. As a general condition, a standard toeboard is required wherever people walk beneath the open sides of a platform or under similar structures or where things could fall from the structure (for example, into the machinery below).

FIXED INDUSTRIAL STAIRS

Accidents involving stairs can arise from many sources: irregular tread or risers, loose coverings, worn surfaces, stepping on objects, bumping head on ceiling and tripping in either ascending or descending. Fixed industrial stairs in the industrial/vocational education shop must conform to requirements for safety (OSHA 1910.24 and 23).

1. *Stair Strength.* Fixed stairways must be designed and constructed to carry a load five times the normal live load anticipated. As a minimum they must be able to carry safely a moving concentrated load of 1,000 pounds.

6-1/2" = 16.5 cm.
9-1/2" = 24.1 cm.

2. *Risers.* Riser heights must be uniform throughout any flight of stairs. They should be no less than 6-1/2 inches nor more than 9-1/2 inches.

9-1/2" = 24.1 cm.

3. *Tread Widths.* Tread widths, like riser heights, must be uniform throughout any flight of stairs. Tread width of not less than 9-1/2 inches plus nosing is recommended. All treads must be reasonably slip-resistant.

1/2" = 13 mm.
1" = 25 mm.

4. *Nosings.* Stair treads and the top landing of a stairway, where risers are used, should have a nose which extends 1/2 to one inch beyond the face of the lower riser. Noses should have an even leading edge. Nosings must be of non-slip finish.

5. *Stair Width.* The minimum width is 22 inches.

22" = 55.9 cm.

6. *Stairway Railings and Guards.* If the flight of stairs has four or more risers, the following guardrail system is required:

   a. on stairways less than 44 inches wide having both sides enclosed, at least one handrail, preferably on the right hand descending

   44" = 112 cm.

   b. on stairways less than 44 inches wide having one side open, at least one stair railing on the open side

   44" = 112 cm.

   c. on stairways less than 44 inches wide having both sides open, one stair railing on each side

   d. on stairways more than 44 but less than 88 inches wide, one handrail on each enclosed side and one stair railing on each open side

   88" = 224 cm.

   e. on stairways 88 or more inches wide, one handrail on each enclosed side, one stair railing on each open side, and one intermediate stair railing located approximately midway of the width

7. *Vertical Clearance.* Vertical clearance above any stair tread to an overhead obstruction must be at least seven feet, measured from the leading edge of the tread.

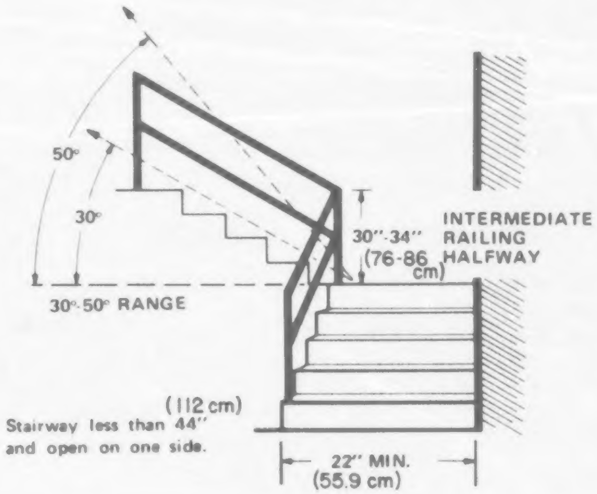
7' = 2.1 m.

8. *Lighting.* All stairs should be adequately lighted.

9. *Handrails.* Stairs must have handrails 30 to 36 inches high as measured from the tread at the upper face of the riser.

30" to 36" = 76 to 91 cm.

10. *Angle of Stairway Rise.* The angle to the horizontal made by the stairs must be between 30° and 50°.


50°
30°
30°-50° RANGE
30"-34"
(76-86 cm)
INTERMEDIATE RAILING HALFWAY
(112 cm)
Stairway less than 44" and open on one side.
22" MIN.
(55.9 cm)

Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, Feburary 1979), p. 38.

Flights have from four to seventeen treads between landings. Twelve treads are recommended as an average for comfort and uniformity.

FIXED LADDERS

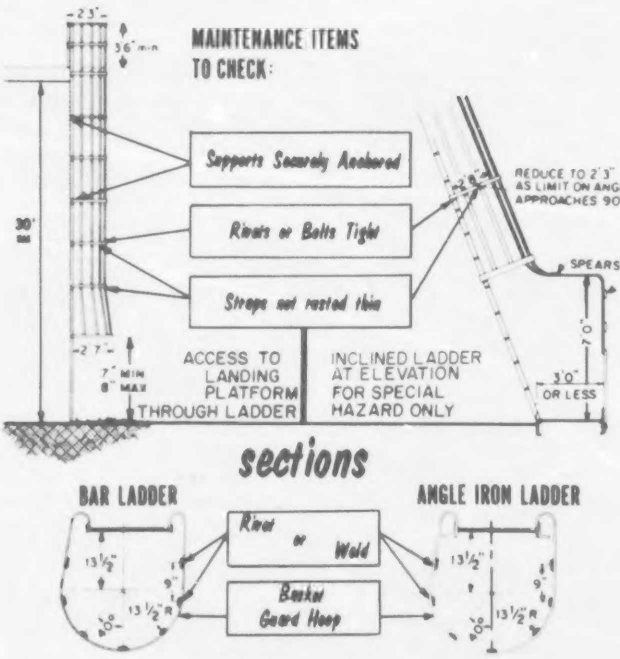
Ladders must be purchased wisely, maintained properly and used carefully. They can fall or slip; students can fall or slip on or from them; objects can drop or fall on or from them. Metal ladders can cause electrical shock.

At various locations in the school, fixed ladders may be installed for a variety of general and maintenance uses. These ladders should meet the following requirements, set forth in OSHA Safety and Health Standards 1910.27:

1. A fixed ladder must be permanently fastened to an upright surface. It is usually constructed of metal.

20' = 6 m.
42" = 1.1 m.

2. A ladder must have cages or wells on it if it rises more than twenty feet from the floor (see Figure 13). Cages must extend a minimum of 42 inches above the top of a landing


2'3"
3'6" min
MAINTENANCE ITEMS TO CHECK:
Supports Securely Anchored
Rivets or Bolts Tight
Straps not rusted thin
30' max
2'7"
7' MIN 8' MAX
ACCESS TO LANDING PLATFORM THROUGH LADDER
INCLINED LADDER AT ELEVATION FOR SPECIAL HAZARD ONLY
2'6"
REDUCE TO 2'3" AS LIMIT ON ANGLE APPROACHES 90°
SPEARS
7'0"
3'0" OR LESS
sections
BAR LADDER
ANGLE IRON LADDER
Rivet or Weld
Basket Guard Hoop
13½"
9"
13½"R
30°

Pixed Ladder with Cage.
From *Safe Working Surfaces*, U.S. Department of Labor, Bureau of Labor Standards, Bulletin 292 (1967), p. 19.

Figure 13

unless other acceptable protection is provided. They must extend down the ladder to a point seven or eight feet above the base of the ladder. A platform is required every thirty feet for caged ladders and every twenty feet for unprotected ladders (when no ladder safety device is used).

7' to 8' = 2.1 to 2.4 m.
30' = 9 m.
20' = 6 m.

3. Fixed ladders must be designed to withstand a single concentrated load of at least 200 pounds.

200 lbs. = 91 kg.

4. Rungs of metal ladders must have a minimum diameter of 3/4 inch. Rungs of wood ladders must have a minimum diameter of 1-1/8 inches.

3/4" = 19 mm.
1-1/8" = 39 mm.

5. Rungs must be at least sixteen inches wide, be spaced no more than twelve inches apart and be uniform throughout the length of the ladder. Rungs, cleats and steps must be free of splinters and burrs.

16" = 41 cm.
12" = 30 cm.

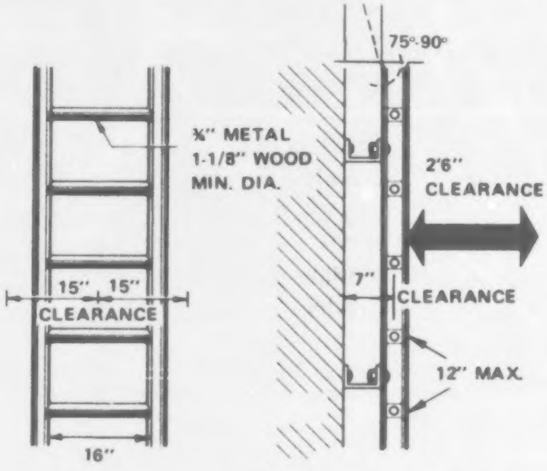
6. Ladders, when their construction and location so requires, must be treated with a preservative to resist deterioration. Note that paint will not adequately preserve a wooden ladder.

2-1/2' = 76 cm.

7. The preferred pitch for safe descent is 75° to 90°. Unless caged or equipped with a ladder safety device, ladders with 90° pitch must have a 2-1/2-foot clearance on the climbing side.

7" = 18 cm.

8. There must be at least a seven-inch clearance in back of the ladder to provide adequate toe space (see Figure 14).



3/4" = 1.9 cm.
1-1/8" = 2.9 cm.
15" = 38 cm.
16" = 40.6 cm.

2'6" = 76 cm.
7" = 17.8 cm.
12" = 30 cm.

From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 37.

Figure 14

PORTABLE LADDERS

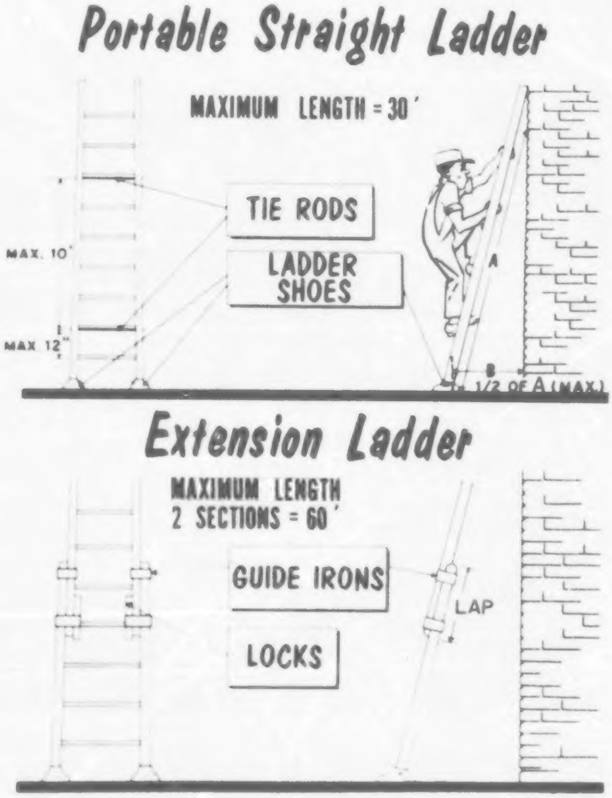
Throughout the industrial/vocational education complex, portable ladders are used for a variety of tasks. Among the most common portable ladders found in the shop area are those made of wood, steel, aluminum, magnesium alloy and fiberglass.

A straight ladder consists of two beams (side rails) and rungs (cross members). The top end of the ladder is called the tip and the bottom the base.

A standard ladder will have its rungs equally spaced twelve inches on center and have a minimum of two metal cross braces set at a maximum distance of ten feet apart (see Figure 15). Single ladders must be no more than thirty feet long. Two-section extension ladders must not exceed sixty feet.

12" = 30 cm.

10' = 3 m.
30' = 9 m.
60' = 18 m.


Portable Straight Ladder
MAXIMUM LENGTH = 30'
TIE RODS
LADDER SHOES
MAX. 10'
MAX. 12"
A
B
1/2 OF A (MAX.)
Extension Ladder
MAXIMUM LENGTH 2 SECTIONS = 60'
GUIDE IRONS
LOCKS
LAP

18" = 30 cm.
10' = 3 m.
30' = 9.1 m.
60' = 18.3 m.

From *Safe Working Surfaces,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 292 (1967), p. 13.

Figure 15

Defective Ladders

Defective ladders must not be used. Ladders are defective if they have defects in the wood, crossgrain knots, cracks, checks, shades, decay, loose or broken rungs or pitch pockets.

Extension Ladders

An extension ladder consists of a bottom section called the bed and a movable top section called the fly. The fly is extended from the bed by a lanyard and pulley arrangement and locks on the rungs of the bed ladder with automatic locks called dogs.

When examining extension ladders, take care to be sure that automatic locks are operable, free from defects, and work efficiently by gravity alone. Also consider the size and condition of the rope and the condition of the hoisting pulley. Worn, undersized rope should be replaced as should rusted parts and pulleys which are not anchored properly or do not turn freely.

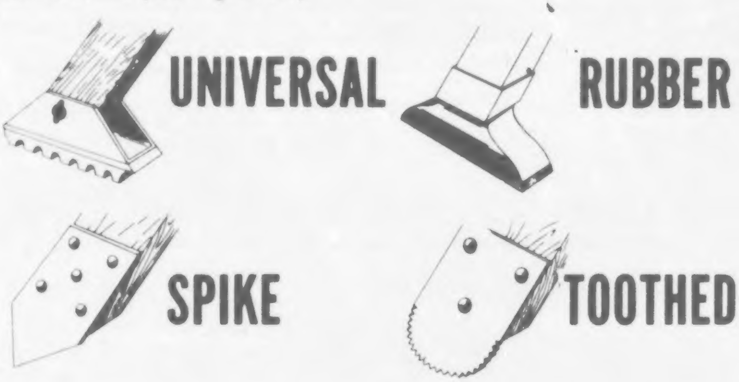
Lapping Strengths

36' = 11 m.
3' = .9 m.
48' = 14.6 m.
4' = 1.2 m.
60' = 18.4 m.
5' = 1.5 m.

Lapping means that one section overlaps with another to give strength to the ladder where sections meet. On two-section extension ladders, the minimum overlap for the two sections is specified in OSHA 1910.25: for ladders up to and including 36 feet, a three-foot overlap; for ladders between 36 and 48 feet, a four-foot overlap; for ladders from 48 to 60 feet, a five-foot overlap.

Non-Slip Bases

It is recommended that all portable ladders be equipped with nonslip bases to provide for adequate traction. There are four common nonslip bases for ladders: universal, rubber suction, spike and toothed (see Figure 16).



Nonslip Ladder Bases.
From *Safe Working Surfaces,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 292 (1967), p. 15.
Figure 16

Universal

1. The so-called "universal" ladder shoe can be used on solid surfaces with the corrugated surface down, or with the spike turned down for use on soft footing such as the ground. These shoes are obtainable with corrugated surfaces made of cork, rubber, cord or abrasive materials.

Rubber Suction

2. The rubber suction surface shoe is available in rubber, neoprene or cord and is excellent for wet, smooth surfaces.

Spike

3. So-called "spike" shoes have spikes made of metal, generally of steel or bronze, and are used outdoors.

Toothed

4. Toothed shoes are used for work on construction, especially concrete floors, sidewalks or asphalt surfaces.

Chemical Decomposition

In those areas where oil or certain solvents may be contacted, rubber should not be used on ladder shoes because of the effect of the solvents on rubber. Neoprene and some other plastics are not affected by oil.

Maintenance

Ladder shoes must be maintained in efficient condition. When they no longer serve the purposes intended, they should be discarded and replaced with new ones.

LADDER SAFETY

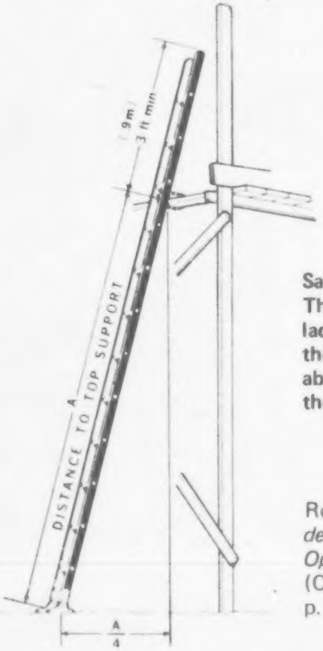
No matter how well constructed and maintained, ladders are safe only when used properly. The following practices should be observed when placing ladders:[2]

Ladder Placement

1. Be sure that the horizontal distance from the base to the vertical plane of the support is approximately one-fourth the ladder length between supports (see Figure 17). For example, place a twelve-foot (3.7 m.) ladder so that the bottom is three feet (.9 m.) away from the object against which the top is leaning.

2. Never use a ladder in a horizontal position [illegible] a runway or scaffold. Single and extension ladders are designed for use in a nearly vertical position and cannot be used safely in a horizontal position or with the base at a greater distance from the support than indicated in #1.

3. Never place a ladder in front of a door that opens toward the ladder unless the door is locked, blocked or guarded.



Safe procedure in setting up a ladder. The base should be one-fourth the ladder length from the vertical plane of the top support. Where the rails extend above the top landing, ladder length to the top support only is considered.

Reprinted with permission from *Accident Prevention Manual for Industrial Operations—Engineering and Technology* (Chicago: National Safety Council, 1980), p. 55.

Figure 17

4. Place a portable ladder so that both side rails have secure footing. Provide solid footing on the ground to prevent the ladder from sinking.

5. Place the ladder feet on a substantial and level base, never on movable objects.

6. Never lean a ladder against unsafe backing such as loose boxes or barrels.

7. When using a ladder for access to high places, securely lash or otherwise fasten the ladder to prevent its slipping.

8. When using a ladder for access to a scaffold, secure both bottom and top to prevent displacement.

3' = .9 m.

9. Extend the ladder side rails at least three feet above the top landing.

10. Do not place a ladder close to live electric wiring or against any operational piping (acid, chemical, sprinkler system, etc.) where damage may be done.

11. Avoid using metal ladders where they might come in contact with electric circuits. If such use cannot be avoided, take proper safety measures to prevent short circuits or electrical shock.

Ascending or Descending Ladders

The following practices should be observed when ascending or descending ladders:[3]

1. Hold on with both hands when going up or down. If material must be handled, raise or lower it with a rope either before going down or after climbing to the desired level.
2. Always face the ladder when ascending or descending.
3. Never slide down a ladder.
4. Be sure that your shoes are not greasy, muddy or slippery before you climb.
5. Do not climb higher than the third rung from the top on straight or extension ladders or the second tread from the top on stepladders.

Ladder Maintenance

As part of the school safety and health inspection program, ladders should be thoroughly inspected every three months. The routine inspection form in Figure 19 highlights the major areas to be inspected. An accurate record of each inspection should be kept.

Coating Ladders

The Safety Code for Portable Wood Ladders, ANSI A14.1, states that "ladders should be kept coated with a suitable protective material. The painting of ladders is satisfactory providing the ladders are carefully inspected prior to painting by competent and experienced inspectors acting for and responsible to the purchaser, and the ladders are not for resale." However, a clear wood preservative such as linseed oil is a better choice than paint. It does not cover up defects, and it provides better traction overall.

If a ladder is to be coated, it must be coated completely. Otherwise the uncoated portions attract moisture, which cannot leave the wood because of the more or less impervious coating. In such a case the protective coating encourages rather than retards decay.

SCAFFOLDS

Scaffolds are temporary elevated working platforms designed to support both workers and materials. The major hazards which scaffolds present are the danger of people or equipment falling; accidents when getting on or off; objects falling from above onto those on scaffolds; mobile scaffolds rolling; and the setting, shifting, breaking loose or collapse of the scaffolding itself.

LADDER INSPECTION CHECKLIST

General	**Item To Be Checked**	**Needs Repair**	**Condition O.K.**
	Loose steps or rungs (considered loose if they can be moved at all with the hand)	☐	☐
	Loose nails, screws, bolts, or other metal parts	☐	☐
	Cracked, split, or broken uprights, braces, steps, or rungs	☐	☐
	Slivers on uprights, rungs, or steps	☐	☐
	Damaged or worn nonslip bases	☐	☐
Stepladders			
	Wobbly (from side strain)	☐	☐
	Loose or bent hinge spreaders	☐	☐
	Stop on hinge spreaders broken	☐	☐
	Broken, split, or worn steps	☐	☐
	Loose hinges	☐	☐
Extension Ladders			
	Loose, broken, or missing extension locks	☐	☐
	Defective locks that do not seat properly when the ladder is extended	☐	☐
	Deterioration of rope, from exposure to acid or other destructive agents	☐	☐
Trolley Ladders			
	Worn or missing tires	☐	☐
	Wheels that bind	☐	☐
	Floor wheel brackets broken or loose	☐	☐
	Floor wheels and brackets missing	☐	☐
	Ladders binding in guides	☐	☐
	Ladder and rail stops broken, loose, or missing	☐	☐
	Rail supports broken or section of rail missing	☐	☐
	Trolley wheels out of adjustment	☐	☐
Trestle Ladders			
	Loose hinges	☐	☐
	Wobbly	☐	☐
	Loose or bent hinge spreaders	☐	☐
	Stop on hinge spreader broken	☐	☐
	Center section guide for extension out of alignment	☐	☐
	Defective locks for extension	☐	☐
Sectional Ladders			
	Worn or loose metal parts	☐	☐
	Wobbly	☐	☐
Fixed Ladders			
	Loose, worn, or damaged rungs or side rails	☐	☐
	Damaged or corroded parts of cage	☐	☐
	Corroded bolts and rivet heads on inside of metal stacks	☐	☐
	Damaged or corroded handrails or brackets on platforms	☐	☐
	Weakened or damaged rungs on brick or concrete slabs	☐	☐
	Base of ladder obstructed	☐	☐
Fire Ladders			
	Markings illegible	☐	☐
	Improperly stored	☐	☐
	Storage obstructed	☐	☐

Reprinted with permission from *Accident Prevention Manual for Industrial Operations,* 7th ed. (Chicago: National Safety Council, 1974), p. 415.

Figure 18

Most scaffolds fall into one of three primary categories: wood pole, tube and coupler and tubular welded frame.

Wooden Pole

Wooden pole scaffolds are sometimes classified according to their use: light duty (e.g., plastering, lathing) and heavy duty (stonemasonry, bricklaying).

Tube and Clamp (Coupler)

Tube and clamp (coupler) scaffolds are an assembly consisting of tubing which serves as posts, bearers, braces, ties and runners, a base supporting the posts and special couplers which serve to connect the uprights and to join the various members.

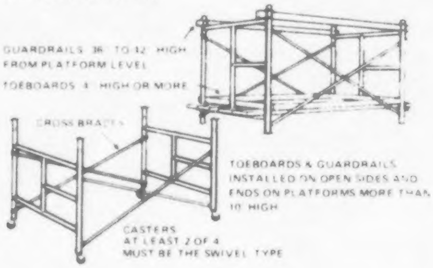
Tubular Welded Frame

Tubular welded frame scaffolds are built up of prefabricated welding sections consisting of posts and bearers with intermediate connecting members. They are braced with diagonal or cross braces. Such scaffolds are quicker and easier to set up than wooden pole scaffolds.

Because tubular metal scaffolding is readily available, versatile, adaptable to all scaffolding problems and economical, it is generally used. Most manufacturers and suppliers of tubular metal scaffolding provide engineering service to help in the design of adequate scaffolding for any situation. Many suppliers also furnish erection and dismantling service.

Mobile (Rolling) Scaffolds

Some scaffolding is mobile or rolling. These are caster-mounted sections of tubular metal scaffolds (see Figure 19) or are made of components specifically made for the purpose. When mobile (rolling) scaffolding is used, additional precautions must be taken to ensure safety. These are spelled out in OSHA Safety and Health Standards 29 CFR 1910.29.


GUARDRAILS 36" TO 42" HIGH FROM PLATFORM LEVEL
TOEBOARDS 4" HIGH OR MORE
CROSS BRACES
TOEBOARDS & GUARDRAILS INSTALLED ON OPEN SIDES AND ENDS ON PLATFORMS MORE THAN 10' HIGH
CASTERS AT LEAST 2 OF 4 MUST BE THE SWIVEL TYPE

36" to 42" = 91 cm. to 107 cm.
4" = 10 cm.
10' = 3 m.

From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 41.

Figure 19

General Requirements for Scaffolds

The following are general requirements for all scaffolding (see 1910.28):

1. All scaffolding must be sound, rigid footing or anchorage, capable of holding the intended load without settling or shifting. Unstable objects such as barrels, boxes, loose bricks or concrete blocks must not be used to support scaffolds or planks.

10' = 3 m.

4' to 10' = 1.2 to 3 m.
45" = 114 cm.

2. Guardrails and toeboards must be used on all open sides and ends of platforms which are more than ten feet above the ground or floor (except needle beam scaffolds and floats in use by structural iron workers). Scaffolds four to ten feet high which are less than 45 inches wide must also have guardrails.

3. An access ladder or equivalent safe access must be provided.

4. Scaffolds and their components must be able to support at least four times the maximum intended load. Scaffolds must not be in excess of the working load for which they are intended. Wire or fiber rope used for scaffold suspension must be capable of supporting at least six times the intended load.

12" = 30 cm.

5. All planking or platforms must be overlapped at least twelve inches or secured from movement.

6" = 15 cm.
18" = 46 cm.
12" = 30 cm.

6. Planks must extend over the end supports not less than six inches or more than eighteen inches (not more than twelve inches on construction sites), and should be secured from falling off the platform.

7. Scaffolds must be secured when in use and must not be moved when in use or occupied.

8. All scaffolds must be maintained in a safe condition at all times. Unsafe scaffolds should be removed from the site for disposal or the defective parts immediately replaced or repaired.

9. The poles, legs or uprights of scaffolds must be plumb and securely and rigidly braced to prevent swaying and displacement.

10. Planking must be scaffold grade for the species of wood used if the scaffold is of the wood pole type. The maximum permissible spans for two-by-nine inch or wider planks are as follows:

2" x 9" = 5 cm. x 23 cm.

MATERIAL					
	FULL THICKNESS UNDRESSED LUMBER			NOMINAL THICKNESS LUMBER	
Working Load (p.s.f.)	25	50	75	25	50
Permissible Span (ft.)	10	8	6	8	6

The maximum permissible span for 1¼ x 9 inch or wider plank of full thickness is four feet, with medium loading of 50 p.s.f.

1-1/4" x 9"
= 3 cm. x 23 cm.
4' = 1.2 m.

11. Where there are overhead hazards, overhead protection must be provided. No one should work on scaffolds during storms or high winds.

CONCLUSION

The construction or purchase of safe floors, ramps, railings, stairs, ladders and scaffolding is the first step in providing safe working surfaces in the industrial/vocational education shop. The second step is properly maintaining these structures, and the third step is using them properly. If these three steps are taken, many accidents will be prevented and a safer shop environment will result.

NOTES

1. The sections Standard Railings and Toeboards, Fixed Industrial Stairs, Fixed Ladders and Scaffolds have been carefully reviewed by OSHA staff members. In order that this instructional material contain the most current information available, it includes those revisions which are planned in General Industry OSHA Safety and Health Standards, 29 CFR Part 1910, Subpart D.

2. Adapted from *Accident Prevention Manual for Industrial Operations* (Chicago: National Safety Council, 1974), pp. 416–417, and *General Industry OSHA Safety and Health Standards (29 CFR 1910)*, U.S. Department of Labor, November 7, 1978, pp. 25–28.

3. *Accident Prevention Manual for Industrial Operations*, p. 417.

QUESTIONS AND ANSWERS

1. **Name the two broad classifications of falls.**

a. Fall from the same level

b. Fall from different levels

2. **Slippery floors are a hazard in the school shop. They are most commonly caused by . . .**

Spilling of water or other liquids such as grease or oil.

3. **Three reasons for uneven floors in the shop are . . . .**

Any three from among the following:

a. warping

b. loose boards

c. excessively worn surfaces

d. settling of the building

e. improper alignment of floor

f. depressions, cracks or ruts

4. What is a standard guardrail system? 42" = 107 cm. 2" = 5 cm. 4" = 10 cm.

A standard guardrail system consists of a top rail, midrail and posts with a vertical distance of 42 inches (plus or minus two inches) from the upper surface of the top rail to the floor, runway or platform. A four-inch toeboard should be provided on open sides.

5. What are the four common nonslip bases for ladders?

a. universal

b. rubber suction

c. spike

d. toothed

6. What is the formula for placing a portable ladder against a building? 12' = 3.7 m. 3' = .9 m.

The horizontal distance from the base to the vertical plane of the support should be approximately one-fourth of the ladder length between supports. Thus a twelve-foot ladder should be placed so that the bottom is three feet away from the object on which it is leaning.

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UNIT 10

MAINTAINING THE INDUSTRIAL/VOCATIONAL SCHOOL SHOP

METHODS	Lecture, Class Participation	LENGTH: 45 Minutes
PURPOSE	To examine the roles of preventive maintenance and housekeeping in the school shop safety and health program.	
OBJECTIVES	To introduce the participant to: 1. General maintenance functions 2. Advantages of preventive maintenance 3. Principles of maintenance management 4. Elements in a preventive maintenance program 5. Benefits of good housekeeping 6. Conditions which indicate poor housekeeping 7. Keys to good housekeeping.	
SPECIAL TERMS	1. Preventive Maintenance 2. Accident Prevention Tags	
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Overhead Transparencies, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials	

UNIT 10

MAINTAINING THE INDUSTRIAL/VOCATIONAL SCHOOL SHOP

INTRODUCTION

Even when safety and health were prime considerations in planning and constructing an industrial/vocational school shop, the shop can teem with hazards if the facilities are not properly maintained. Since they may be considered different sides of the same coin, both preventive maintenance and housekeeping will be discussed in this unit.

PREVENTIVE MAINTENANCE: A SHARED RESPONSIBILITY

Maintenance Personnel

Maintenance is an important aspect of the total industrial/vocational education safety and health program. Insufficient or improper maintenance can result in accidents, property damage and equipment breakdown. Although many activities described in this unit are usually done by maintenance personnel, preventive maintenance must be understood as a shared responsibility.

Students

Students caring for tools and equipment accomplish specific maintenance tasks.

Student Shop Foremen
Instructors
Department Heads

The student shop foreman, the instructor and the department head perform other maintenance duties (e.g., oiling, tightening guards, adjusting tool rests, replacing wheels) and monitor the preventive maintenance program.

Shop Safety and Health Committee

The Shop Safety and Health Committee can help maintenance personnel to set up schedules for servicing or replacing machinery and equipment parts; committee members, during their periodic inspections, see that preventive maintenance functions are being performed satisfactorily.

FUNCTIONS OF MAINTENANCE

Maintenance has four main functions which affect safety and health:

Installing, Constructing and Maintaining Buildings, Facilities, Equipment and Machinery

1. *installing, constructing and maintaining buildings, facilities, equipment and machinery.* By assuring that all plant and facilities design, layout, construction and installation work conforms to good engineering and shop practices, the maintenance organization has taken an important first

step toward the reduction of hazards and potential accidents.

Providing Utility Services for Shop Operations

2. *providing utility services (heat, light, power, compressed air, etc.) for shop operations.* During these activities, maintenance makes sure that acceptable standards are being followed and that hazards which have the capacity to cause accidents are located.

Cleaning Facilities and Disposing of Wastes

3. *providing for the cleaning of facilities and the disposal of scrap materials and waste.* These functions are not simply pushing brooms and taking out the garbage. Windows and lighting fixtures must be cleaned regularly to provide necessary illumination. Certain materials must not be drained into a public sewage system; chemical wastes and acids should be removed in prescribed containers.

Providing Planned Preventive Maintenance

4. *providing planned preventive maintenance on all buildings, electrical systems, machinery and equipment.*

This unit will concentrate on the last two maintenance functions.

DEFINITION OF PREVENTIVE MAINTENANCE

Preventive maintenance may be defined as orderly, uniform, continuous and scheduled action by the maintenance organization to prevent breakdown and prolong the useful life of equipment and buildings.

ADVANTAGES OF PREVENTIVE MAINTENANCE

Some advantages to be gained from preventive maintenance include safer working conditions, more training time on the equipment, decreased "down time" of equipment because of breakdown and increased life of the equipment.

Safer Working Conditions

Poor maintenance can cause accidents. If a guard is not replaced after it has been removed for routine lubrication or repair, then maintenance personnel have created a new hazard. Proper maintenance eliminates hazards instead of making them. For example, during routine maintenance a local exhaust system might be found with its fan not operating or with a substantial amount of airborne dust around the exhaust hood. In any case, the exhaust system cannot function properly and requires attention. In another situation, wires with frayed insulation might be discovered, indicating the need for repairs.

Increased Training Time, Decreased "Down Time"

The proper maintenance of the shop and its equipment is essential to the continuity of the industrial/vocational education program.

Satisfactory operating results are contingent upon having buildings, equipment, machinery, portable tools, safety devices and the like in operating condition and maintained in such a manner that instructional activities will not be interrupted while repairs are being made or equipment replaced. Because preventive maintenance reduces the "down time" of machinery, more training time on the equipment is available.

Prolonged Equipment Life

Preventive maintenance prolongs the life of the equipment by ensuring its proper use. When maintenance personnel and instructors cooperate to make sure that tools are dressed or sharpened and in satisfactory condition, the right tool will be used for the job. When safe and properly maintained tools are issued, students have an added incentive to give the tools better care.

When repairs are made so that equipment is not inoperative for long periods of time, students do not need to improvise by using a piece of equipment for a purpose for which it was not intended. Sound and efficient maintanance management anticipates machine and equipment deterioration and sets up overhaul procedures designed to correct defects as soon as they develop. Such a repair and overhaul system obviously requires close integration of maintenance with shop inspection.

PRINCIPLES OF MAINTENANCE MANAGEMENT

The basic principles of maintenance management are organization, motivation and control.

Organization

Organizing means:

1. establishing policies and procedures for operating the program
2. designating and assigning staff to supervise and carry out the maintenance activities
3. providing them with the means to get the job done.

Maintenance personnel must have the proper tools, materials and equipment to do the job that needs to be done when it needs to be done, without undue delay and without requiring the machines or equipment to be partly torn down or out of order any longer than necessary.

Motivation

Motivation involves instilling a strong sense of responsibility in all maintenance personnel to assure that they will take care of their duties conscientiously and carefully. This involves training them in the safe procedures to be following during maintenance and in the keeping of good records.

Control

Control is concerned with the actual activity of preventive or corrective maintenance. The more efficient preventive maintenance is, the fewer times more expensive actions will be necessary. Overall control is a supervisory function. Maintenance management requires that one person in the organization be responsible for seeing that all phases of the program are operating in accordance with policy and procedures.

COMPONENTS OF PREVENTIVE MAINTENANCE

Preventive maintenance has four main components:

1. scheduling and performing periodic maintenance functions
2. keeping records of service and repairs
3. repairing and replacing equipment and equipment parts
4. providing spare parts control.

Scheduling and Performing Maintenance

Maintenance schedules can be set up on either a time or use basis, whichever comes first. Factors to be considered include

- the age of the machine
- the number of hours per day the machine is used
- past experience
- the manufacturer's recommendations.

Manufacturer's specification provide standards which need to be maintained for safe and economical use of the machine. These specifications give maintenance personnel definite guidelines to follow.

Activities to be Scheduled

Examples of various activities which need to be scheduled include:

- lubricating each piece of equipment
- replacing belts, pulleys, fans and other moving parts

- checking and adjusting brakes.

Recordkeeping

Two kinds of records need to be kept. The first is a maintenance service schedule for each piece of equipment in the shop. Such a schedule indicates the date the equipment was purchased or placed in operation, its cost (if known), the shop in which it is used, each part to be serviced, the kind of service required, the frequency of service and the one assigned to do the servicing.

Each piece of equipment also requires a repair record, which includes an itemized list of parts replaced or repaired and the name of the person who did the work.

Repair and Replacement

In addition to scheduled adjustments and replacements, maintenance personnel are presented with malfunctioning or broken equipment. Repairs should be made in accordance with manufacturer's specifications. Sometimes equipment must be sent back to the manufacturer or his representative for repair. Maintenance personnel should be aware of their limitations and recognize that their experience and expertise is not sufficient for all repairs.

Those assigned repair responsibilities require special safety training. Jobs to be performed include testing or working on equipment with guards and safety devices removed. Therefore, a statement of necessary precautions should accompany the repair directive.

Maintenance personnel, along with instructors and Shop Safety and Health Committee members, have a responsibility to tag and/or lock out defective equipment. Tags are not to be considered a complete warning method but should be used until the hazard can be eliminated. For example, a "Do Not Start" tag on power equipment should be used only until the switch on the system can be locked out. A "Defective Equipment" tag on a damaged ladder is a temporary expedient while making immediate arrangements for the ladder to be taken out of service and sent to be repaired.

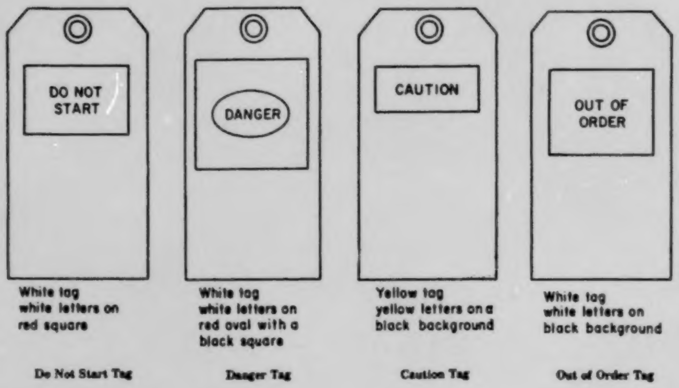
Accident Prevention Tags

The industrial/vocational education shop requires four kinds of accident prevention tags (see OSHA 1910.145).

1. *Do Not Start* tags must be conspicuously located or so placed that they effectively block the starting mechanism. They are to be used when energizing the equipment would cause a hazardous condition.

2. *Danger* tags indicate that an immediate hazard exists and that special precautions are necessary.
3. *Caution* tags warn against potential hazards or caution against unsafe practices.
4. *Out of Order* tags indicate just what they say, that the equipment or machinery is out of order and should not be used.

Figure 20 gives OSHA specifications for tags.


DO NOT START
DANGER
CAUTION
OUT OF ORDER
White tag white letters on red square
White tag white letters on red oval with a black square
Yellow tag yellow letters on a black background
White tag white letters on black background
Do Not Start Tag
Danger Tag
Caution Tag
Out of Order Tag

Accident Prevention Tags.
Reprinted from *General Industry OSHA Safety and Health Standards (29 CFR 1910.145),* U.S. Department of Labor, January 1976, p. 260.

Figure 20

Spare Parts Control

Another element of the total preventive maintenance program is the survey of spare parts requirements. In order to keep needed parts on hand, it is necessary to review periodically material required for repair orders and the delivery schedule of such parts. If maintenance personnel keep purchasing agents informed of their anticipated stock needs, it can prevent lengthy "down time" while waiting for parts to arrive.

EXAMPLES OF EFFECTIVE PREVENTIVE MAINTENANCE

What are some specific ways that preventive maintenance can make the shop environment a safe one? Some examples:

- Make certain that electrical wires have adequate insulation.
- Store compressed gas cylinders properly.
- Tag out unsafe equipment.

- Maintain brakes on materials-handling equipment.
- Replace guards on machinery.
- Properly identify high and low pressure steamlines, compressed air and sanitary lines.
- Maintain boilers and pressure vessels.
- Be careful not to over-oil motor bearings so that oil is not thrown onto the insulation of electrical windings and onto the floor adjacent to the equipment.

Instructor Note:
Instructor asks for positive remarks from participants about ways that preventive maintenance can make the shop environment a safe one. He writes the examples given on the chalk board.

PROGRAM EVALUATION

As part of its inspection function, the Shop Safety and Health Committee will check periodically to make sure that preventive maintenance functions are being adequately defined and satisfactorily performed. Department heads, instructors and students also will be exercising a control function, seeing that equipment is maintained correctly. Maintenance personnel need to understand that inspections are aimed at fact-finding, not faultfinding, and that they share with other school staff an obligation for maintaining a safe facility.

SUPPORTING THE PREVENTIVE MAINTENANCE PROGRAM

The instructor and student can support the preventive maintenance program by contributing their own insights. The following examples show ways that the effectiveness of the program can be measured and increased:

1. *Hand tools.* Instructors and students know the condition of those in use at the machine and on the benches. Is there a system of replacing or repairing defective tools?
2. *Electric wires, operating switches and control boards.* Are these kept in good condition? Are "temporary" repairs, alterations and additions eliminated? Temporary jobs tend to become permanent unless carefully limited to those jobs that are absolutely necessary and made standard immediately after the emergency has passed.
3. *Sound of operating equipment.* Instructors and students soon become accustomed to the tune of equipment, each of which has a characteristic operating sound. They can tell when a machine is overloaded by the noise, the grunt, the squeal; they can tell that maintenance is required because of the rattle and vibration.

4. *Servicing and repair records.* Instructors and students will be able to see when servicing schedules are being kept. These records must be rigidly adhered to, particularly as they affect electrical hoisting equipment, pressure vessels, guards, cranes, slings, chains and tackle, extension cords, portable motor-operated tools and personal protective equipment.

DISTINGUISHING A MEDIOCRE FROM A SUPERIOR MAINTENANCE PROGRAM

The difference between a mediocre maintenance program and a superior one is that the first is aimed at maintaining facilities, the second at improving them. If conditions are good, a mediocre program will keep them that way but will not make them better; if conditions are not good, a mediocre program will not improve them. Preventive maintenance, on the other hand, is a program of mutual support which creates safe conditions, eliminates costly delays and breakdowns and prolongs equipment life.

ROLE OF HOUSEKEEPING IN SAFETY AND HEALTH PROGRAMS

Shop housekeeping plays an important role in the safety and health program. Good housekeeping reduces accidents, improves morale and increases shop efficiency and effectiveness. In a clean and orderly shop people enjoy working and can accomplish their tasks without interference and interruption.

A school shop, by its very nature, contains tools which must be kept organized and machinery which must be kept clean. In its operation it uses flammable substances and materials which require special storage and removal. It generates dust, scrap metal filings and chips, waste liquids and scrap lumber which must be disposed of.

Shop housekeeping is a continuous process, both during and at the end of class. It involves instructors and students alike. Though it may seem humdrum and boring at times, it is, nevertheless, the single most important ingredient in reducing injuries in the school shop.

BENEFITS OF GOOD HOUSEKEEPING

Seeing Housekeeping as Part of Performance

A good housekeeping program incorporates the housekeeping function into all processes, operations and tasks performed in the shop. The ultimate goal is for each student to see housekeeping as an integral part of performance, not as a supplement to the job to be done. When students are educated and trained to appreciate the relationship between housekeeping and performance, the benefits will accrue not only to the industrial/vocational education program in which the students are working today but also to the industries in which they will be working in the future.

A well administered housekeeping program produces other immediate and long-range results.

Reducing Operating Costs

When the shop is clean and orderly and the housekeeping program becomes a standard part of operations, less time and effort will be spent keeping it clean, making needless repairs, and replacing equipment, fixtures and the like.

Increasing Task Performance

When the student can concentrate on his required tasks without excess scrap material, tools and equipment interfering with his work, he can create a product of higher quality and will acquire a higher degree of skill.

Improving Shop Tool and Equipment Control

When everything in the shop has an assigned place, there is less chance that materials, tools, etc., will be taken from the shop or misplaced. In a few moments, the student shop foreman and instructor can determine what is missing before the class is dismissed. Different colors of paint can be used on the tools to identify the department to which they belong. Tool racks or holders should be painted a contrasting color as a reminder to students to return the tools to their proper places. The space directly behind each tool should be painted or outlined in color to call attention to a missing tool.

Using Materials and Parts More Efficiently

Money is saved and shop efficiency is increased when students and instructors alike treat shop materials with the care they deserve by minimizing spillage and scrap, by saving pieces of material for use in future projects and by returning even small quantities of parts to their storage area.

Minimizing Time Spent Searching for Items

Students and instructors will be able to use their time for shop work, not searching for tools, materials or parts.

Using Floor Space Efficiently

When aisle and floor space is uncluttered, movement within the shop is easier and safer, and machinery and equipment can be cleaned and maintained.

Reducing Accident Rates

When a shop has adequate work space and when oil, grease, water and dust are removed from floors and machinery, students are less likely to slip, trip, fall or inadvertently come into contact with dangerous parts of machinery.

Raising Morale

When a shop is clean and orderly, the morale of students and instructors is heightened. Students understand and respect orderliness and cleanliness and the place of housekeeping in industrial processes.

Reducing Fire Hazards

When a shop is kept free from accumulations of combustible materials which may burn upon ignition or, in the case of certain material relationships, spontaneously ignite without the aid of an external source of ignition, the chances of fires are minimized. Furthermore, an orderly shop permits easy exit by keeping exits and aisles leading to exits free from obstructions. A neat and orderly shop also makes it easier to locate and obtain fire emergency and extinguishment equipment.

CONDITIONS WHICH INDICATE POOR HOUSEKEEPING

Poor housekeeping is indicated by any of several conditions.

Objects on Floor and in Aisles

1. *Objects on the floor and in the aisles.* This category includes articles which fall from machinery or are dropped in transit, material left over after a repair job is completed, objects which are stored in the aisles and student projects which are stored improperly.

Tools and Equipment Improperly Stored

2. *Tools and equipment improperly stored.* When tools and equipment not in immediate use are left on workbenches or on the floor, storage control breaks down and housekeeping problems result.

Stock Not Stored or Piled Properly

3. *Stock not stored or piled properly.* This includes the whole area of materials storage, which is discussed in the units on shop planning, fire protection and hazardous materials.

Waste Disposal Inadequate

4. *Waste disposal inadequate.* Signs of inadequate waste disposal in the shop are overflowing receptacles for waste and scrap, the lack of disposal of chips and oil, no provision for the safe reclamation of cutting oils, etc.

Dirt, Grime and General Disorder

5. *Dirt, grime and general disorder.* Dust accumulations on windows, skylights and lighting fixtures reduce illumination and increase eyestrain. Other indicators of careless housekeeping include:

   - scrap cuttings on benches or floors
   - mops and brooms stored in areas other than those assigned them
   - sinks and areas around them with accumulations of dirt and grime
   - rubbish on floors and in corners

- oil, grease, cleaning compounds and solvents left on floor.

Combustible Materials Improperly Stored and Disposed of

6. *Combustible materials improperly stored and disposed of.* Good housekeeping requires that there be no accumulation of oil and solvent-soaked rags and that combustible materials be disposed of in suitable receptacles. The safe storage of flammable substances will be discussed in a later unit.

KEYS TO GOOD HOUSEKEEPING

Good housekeeping doesn't just happen. It requires planning, supervision and constant attention to the following areas:

1. providing sufficient work areas and adequate aisles and keeping these clear of accumulation
2. providing a definite place for each object
3. keeping each object in its designated place and returning it after each use
4. adequately disposing of scrap, waste and surplus materials
5. properly storing materials, including stock and potentially hazardous substances
6. cleaning buildings and equipment regularly and cleaning up after each job.

CONCLUSION

Like preventive maintenance, housekeeping is a shared responsibility. During their regular inspections, instructors, student shop foremen and department heads must make sure that hazardous conditions are not present or imminent because of poor housekeeping. Maintenance personnel and the Shop Safety and Health Committee must call attention to deficiencies they note during their periodic inspections.

From the time the student enters the shop, he should be taught to correct the potential hazards he detects rather than to ask himself whether he created the poor housekeeping condition or whether he is responsible for cleaning up. Because the safety and health of everyone in the shop depend upon it, properly maintaining the facility is everyone's job.

QUESTIONS AND ANSWERS

1. **Name four general maintenance functions.**

   a. installing, constructing and maintaining buildings, facilities, equipment and machinery

   b. providing utility services for shop operations

   c. cleaning facilities and disposing of waste

   d. providing planned preventive maintenance.

2. **Define preventive maintenance.**

   Preventive maintenance is the orderly, uniform, continuous and scheduled action by the maintenance organization to prevent breakdown and prolong the useful life of equipment and buildings.

3. **What are three advantages of preventive maintenance?**

   a. safer working conditions and fewer accidents

   b. more training time on equipment and decreased "down time"

   c. prolonged equipment life.

4. What are four components of preventive maintenance?

    a. scheduling and performing periodic maintenance functions

    b. keeping records of service and repairs

    c. repairing and replacing equipment and equipment parts

    d. providing spare parts control.

5. What are five benefits of good housekeeping?

    Any five from among the following:

    a. Housekeeping is seen as part of all processes, operations and tasks performed in the shop.

    b. Operating costs are reduced.

    c. Students can work better and acquire greater skill.

    d. Fewer tools are misplaced or taken from the shop.

    e. Materials and parts are used more efficiently, and less waste occurs.

    f. Time is spent performing shop work, not in searching for tools or materials.

    g. Floor space is used efficiently and safely.

    h. Accident rates are reduced.

    i. Morale is raised.

    j. Fire hazards are minimized.

6. Name four components essential to good housekeeping.

Any four from among the following:

a. providing sufficient work areas and adequate aisles, which are kept clear of accumulation

b. providing a place for each object

c. keeping each object in its place

d. adequately disposing of scrap, waste and surplus materials

e. properly storing materials

f. cleaning buildings and equipment regularly and cleaning up after each job.

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UNIT 11

ILLUMINATION AND COLOR FOR SAFETY

METHODS	Lecture and Demonstration	LENGTH: 60 Minutes
PURPOSE	To examine illumination and color as factors in a safe shop environment.	
OBJECTIVES	To introduce the participant to: 1. Benefits of adequate illumination in the school shop 2. Factors in adequate illumination 3. Factors in poor illumination 4. Types of Lighting 5. Factors in selecting units 6. Role of color in the industrial/vocational education shop 7. Recommended color standards for marking hazards.	
SPECIAL TERMS	1. Quantity 2. Quality 3. Foot Candle 4. Brightness Ratio 5. Glare 6. Reflection	
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Chalk Board/Chalk	
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials	

UNIT 11

ILLUMINATION AND COLOR FOR SAFETY

INTRODUCTION

In Unit 8 adequate illumination was mentioned as essential to a safe and healthy shop environment. Along with such factors as selecting and placing safe machinery and equipment, materials storage, ventilation, aisle arrangement, space for work and materials flow, medical, first aid and electrical considerations, illumination and color have a very important place in the industrial/vocational school safety program.

This unit aims to familiarize the industrial/vocational education supervisor and instructor with the essential facts needed to understand illumination and color: their necessity, benefits, problems and use.

BENEFITS OF ADEQUATE ILLUMINATION IN THE SCHOOL SHOP

The principal reasons for lighting in industrial/vocational education shops and classrooms are to protect students from eyestrain, reduce losses in visual performance and enable instructors and students to detect more readily hazards in the shop environment. With adequate illumination:

1. Errors will be minimized, thus improving work and decreasing accidents.
2. Defects will be detected more easily, improving the quality of any project.
3. The time necessary to determine fine details and to make fine measurements will be reduced.
4. Shop housekeeping will be improved. A well illuminated shop will make rubbish and other waste products more visible, thus encouraging prompt removal.
5. The social climate will be improved. Better lighting tends to promote a more cheerful shop environment and enables colors to be more visible.

FACTORS IN ADEQUATE ILLUMINATION

Simply stated, the factors associated with illumination can be grouped into two broad categories: quantity and quality.

Quantity is the amount of light that produces sufficient brightness to illuminate the task and its surroundings.

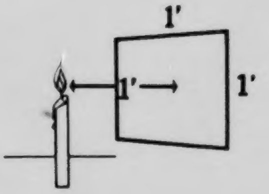
Quality pertains to the distribution of brightness in a visual environment and includes the color of light, its direction, diffusion, degree of glare and so forth.

Quantity

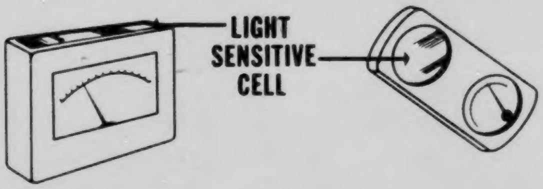
The desirable quantity of light for operations in the industrial/vocational education shop depends primarily upon the task being done. As the quantity of illumination is increased to recommended levels, the ease, speed and accuracy in accomplishing the task are also increased.

Quantity of illumination is measured in units called footcandles, an index of the ability of a light source to produce illumination. A light meter gives a direct reading of the number of footcandles or light reaching the working plane. A footcandle is the amount of illumination on a surface of one square foot, all parts of which are at a distance of one foot from a standard candle.

1. FOOT-CANDLEPOWER



2. INSTRUMENTS



Reprinted from *Illumination for Safety,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 297 (1967), p. 5.

Generally those tasks requiring fine detail, low contrasts, and prolonged work periods require higher illumination levels than more casual or intermittent tasks involving high contrast. The current minimum levels of illumination for industrial areas as recommended by the Illuminating Engineering Society (IES) are given in ANSI/IES RP-7-1979. Table 7 illustrates the quantity of illumination required for various tasks likely to be performed in industrial/vocational education shops.

TABLE 7

RECOMMENDED FOOTCANDLES ON TASKS

The following recommendations represent the minimum on the task at any time for young adults with normal and better than 20/30 corrected vision.

Task	Footcandles
Forging	50
Foundry work	
Annealing (furnaces)	30
Core making	
Fine	100
Medium	50
Pouring	50
Garages (auto shop)	
Repairs	100
Active traffic areas	20
Machine Shops	
Rough bench and machine work	50
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	100
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	500*
Extra-fine bench and machine work, grinding, fine work	1000*
Paint shops	
Dipping, simple spraying, firing	50
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	50
Fine hand painting and finishing	100
Extra-fine hand painting and finishing	300*

TABLE 7 (concluded)

Task	Footcandles
Printing and photoengraving	
Printing	
Color inspection and appraisal	200*
Machine composition	100
Composing	100
Presses	70
Proofreading	150
Photoengraving	
Etching, staging, blocking	50
Routing, finishing, proofing	100
Tint laying, masking	100
Sheet metal shops	
Miscellaneous machines, ordinary bench work	50
Presses, shears, stamps, medium bench work, spinning	50
Punches	50
Tin plate inspection (galvanized)	200**
Scribing	200**
Welding	
General illumination	50
Precision manual arc welding	1000*
Woodworking	
Rough sawing and bench work	30
Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, coopering	50
Fine bench and machine work, fine sanding and finishing	100

*The recommended footcandles may be obtained by a combination of general lighting plus special supplementary lighting. Care must be taken to design and install a system which not only provides sufficient light but directs and diffuses the light and protects the eyes. Insofar as it is possible, glare (both direct and refected) and objectionable shadows should be eliminated.

**In such tasks, the mirror-like surface of the material means that special care must be taken in selecting and placing lighting equipment and/or orienting the work to reduce glare.

Adapted from ANSI/IES RP-7-1979, American National Standard Practice for Industrial Lighting, pp. 11-16.

Usually calculations are based on the illumination of horizontal surfaces. But much shop work is done on slanting and vertical surfaces, where illumination may be only one-half to one-third of that on horizontal surfaces. Compensation must be made and additional illumination provided for such surfaces.

The lighting system also should provide required illumination on tasks located at the sides of the shop, where the illumination is apt to be considerably less than the average calculated level.

Quality

Quality of illumination pertains to the distribution of brightness in the visual environment. Glare, diffusion, direction, uniformity, color, brightness and brightness ratios all have a significant effect on visibility and the ability to see easily, accurately and quickly. Tasks performed over long periods of time and demanding discernment of fine details require illumination of a high quality.

Brightness Ratios

The ability to see detail depends upon there being a difference in brightness between the detail and its background, but the eyes function most comfortably and efficiently when the difference is kept within a certain range. The ratios between areas within the field of vision should not exceed those shown in Table 8, which illustrates the maximum brightness ratios recommended by the Illuminating Engineering Society in ANSI/IES RP-7-1979. The goal in shop illumination should be to have the task brighter than the surroundings.

FACTORS ASSOCIATED WITH POOR ILLUMINATION

Besides the factors of insufficient quality and quantity of illumination, other less tangible factors contribute to accidents. These are:

- direct glare
- reflected glare
- dark shadows
- excessive visual fatigue.

In addition, accidents may be caused by delayed eye adaptation when coming from bright surroundings into darker ones or when coming from dark surroundings into brighter ones.

Glare

Glare is defined as any brightness within the field of vision of such a character as to reduce visibility and cause discomfort, annoyance or eye fatigue. Glare is divided into two types: direct and reflected.

TABLE 8

RECOMMENDED MAXIMUM BRIGHTNESS RATIOS

	Classification		
	A	B	C
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroudnings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	*
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	*
Between lighting units (or windows, skylights, etc.) and surfaces adjacent to them	20 to 1	*	*
Anywhere within normal field of view.	40 to 1	*	*

*Brightness ratio control not practical.

A Interior areas where reflectances of entire space can be controlled

B Areas where reflectances of immediate work area can be controlled but not those of remote surroudings

C Areas where reflectances cannot be controlled and environmental conditions can be altered only with difficulty

Adapted from ANSI/IES RP-7-1979, American National Standard Practice for Industrial Lighting, p. 17.

Direct Glare

Direct glare is the result of a source of illumination within the field of view, whether that source is artificial or natural. To reduce direct glare:

1. Decrease the brightness of the light source. (For example, use a shade.)
2. Reduce the area of high brightness. (For example, install window coverings.)
3. Increase the angle between the glare source and the line of vision. (For example, position the light source so that it no longer falls into the normal field of vision.)
4. Increase the brightness of the general area surrounding the glare source to reduce contrast. (For example, make certain that surface reflectances are at recommended levels.)

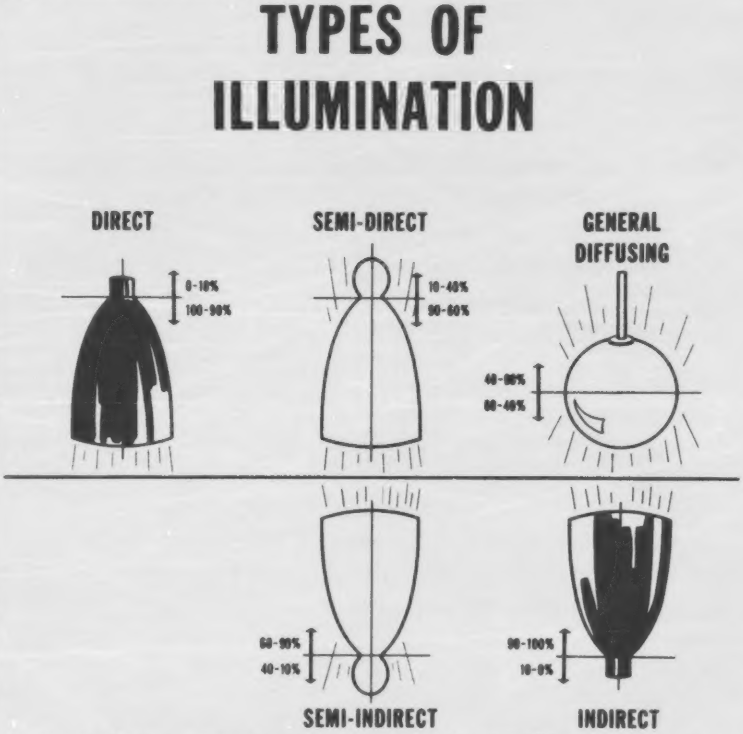
Reflected Glare

Reflected glare is caused by very bright objects or surfaces or by differences in brightness reflected from shiny surfaces (ceilings, walls, machinery). This type of glare is often more annoying and fatiguing to the eyes than direct glare because it is so close to the line of vision that the eye cannot gain relief by moving away from it. To reduce reflected glare:

1. Decrease brightness of the light source but maintain the limits prescribed in the standard. (For example, replace an exposed incandescent lamp with a fluorescent light.)
2. Shield and/or diffuse light source. (For example, use lighting units with "batwing" distribution.)
3. Change the position of either the work or the light source. (For example, raise the position of a wall light fixture.)
4. Reduce the reflecting source physically. (For example, use a dull, flat paint.)
5. Reduce the contrast by increasing surrounding brightness. (For example, bring surface reflectances up to recommended levels.)

TYPES OF LIGHTING

Interior lighting systems are divided into the following types (see Figure 21 and Table 9).


TYPES OF ILLUMINATION
DIRECT
0-10%
100-90%
SEMI-DIRECT
10-40%
90-60%
GENERAL DIFFUSING
40-60%
60-40%
60-90%
40-10%
SEMI-INDIRECT
90-100%
10-0%
INDIRECT

Reprinted from *Illumination for Safety,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 297 (1967), p. 9.

Figure 21

Table 9

Classification	Distribution upward (in percent)	Distribution downward (in percent)
Direct	0 to 10	90 to 100
Semidirect	10 to 40	60 to 90
General diffuse	40 to 60	40 to 60
Semiindirect.	60 to 90	10 to 40
Indirect.	90 to 100	0 to 10

Reprinted from *Illumination for Safety,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 297 (1967), p. 10.

Direct Type

Direct Type — Direct lighting aims practically all of the light downward, directly toward the usual working area. A problem with direct units is that they may cause disturbing shadows. This type is best used to light areas where tasks are vertical or near vertical.

Semi-Direct Type

Semi-Direct Type — Semi-direct lighting units direct from 60 to 90 percent of their light downward. The increased ceiling illumination from the semi-direct distribution of light reduces the brightness ratio between the lighting fixture and the ceiling, softens shadows and increases diffusion.

General Diffuse of Direct-Indirect Type

General Diffuse or Direct-Indirect Type — This classification refers to lighting units in which the downward and upward components are approximately the same (each 40 to 60 percent of the total light output). General diffuse lighting units emit light about equally in all directions. Direct-indirect lighting units emit very little light at angles near the horizontal. The latter are, therefore, generally preferable since they are lower in brightness in the direct-glare zone. This is the type most commonly used for general shop lighting.

Semi-Indirect Type

Semi-Indirect Type — These units direct most of their light (60 to 90 percent of the total light output) upward. The major portion of the light reaching the normal horizontal work plane is reflected from the ceiling and upper walls. When this type of lighting unit is used, it is important to ensure high reflectance by keeping the ceiling and upper walls as clean as possible. This use is generally limited to areas where reflected glare from mirror-like work surfaces must be reduced.

Indirect Type

Indirect Type — These units emit from 90 to 100 percent of their light upward and are seldom used in industrial operations. While this lighting is generally the most comfortable, it is the least utilized and is often difficult to maintain.

FACTORS IN SELECTING LIGHTING UNITS

Types

Either incandescent or fluorescent lighting units, similar to those used in the rest of the school, may be used in the shops. Low-bay improved-color mercury lighting units may also be used. The lighting should follow the best industrial lighting practices, with special emphasis on assisting the accuracy of manual operations and making visible possible elements of danger.

In printing shops parabolic specular metal reflectors or prismatic closure plates, both of which spread the brightness of the lamps out over the width of the reflector, should be used over make-up racks and composing stone. Multiple presses need light, preferably from continuous fluorescent lighting units, directed from the side into the machines. The lighting of the printing shop should have an upward component to light ceiling and upper walls.

In machine shops and metal working areas, a grid system of semidirect fluorescent lighting units will give good results. Localized lighting should supplement general lighting near high speed tools and saws.

Location

Many areas in industrial/vocational education shops (for example, battery charging rooms) may be classified as hazardous. These locations require the use of specialized lighting equipment (vaporproof, explosionproof and dustproof lighting units) which provides required illumination without introducing hazards to life and property.

Maintenance

In selecting suitable lighting units for the industrial/vocational education shop, important factors to consider include:

1. the rate at which the lighting unit will collect dirt
2. the ease with which the lighting unit can be cleaned and lamps replaced.

For example, open-bottom or louvered types offer the advantage of having no bottom surface to collect dust and dirt. Closed-bottom dust-tight units often are selected to prevent dirt and dust accumulation on the lamps and reflecting surfaces.

In order to maintain the original requirement for illumination, it is necessary to set up a maintenance schedule which should include:

- cleaning fixtures.
- cleaning room surfaces and windows. The collection of dirt on room surfaces may decrease their reflectance, thereby reducing the amount of visible light which falls on the working plane. Therefore, rough surfaces which encourage the accumulation of dirt should be avoided.
- replacing worn-out globes and tubes. Care also should be exercised during relamping to ensure adequate sealing against dust. Even a small space left in the gasket seal will allow the lighting unit to breathe dirt.
- repainting fixtures and room surfaces. Consideration for the maintenance schedule should be included in planning plant illumination so that there will be safe access to the

globes, tubes, fixtures, windows and room surfaces for regular scheduled maintenance.

THE ROLE OF COLOR IN THE SCHOOL SHOP

Illumination and color are partners in affecting tasks which involve the eyes. There are several advantages to using color in the industrial/vocational education shop.

1. Color can provide brightness and contrast and therefore can affect visual performance.
2. Color can make the shop environment a more pleasant one, raising morale.
3. Color can result in better housekeeping and improved repair and maintenance.
4. Color can be used as a coding technique to spotlight hazards.

Aid to Visual Performance

The ease and efficiency with which students see can be aided by the judicious selection of colors for painting the industrial/vocational education shop and its contents. Conversely, when a person's eyes are exposed for long periods of time to extreme monotony or high contrast in color and brightness, they will function less efficiently.

Brightness and Contrast

Using color to increase brightness and contrast is a device easily adapted to the shop setting. For example, a white object will appear much brighter than a dark one under the same illumination. Contrast tends to increase visibility by making the task stand out against the background.

Speed of Visibility

The speed of visibility is a direct function of brightness and/or contrast. Increasing either brightness or contrast will shorten visibility time, increase production, decrease errors and mistakes, and possibly give the student and instructor those extra fractions of a second needed to avoid injury.

Psychological Advantages

Besides the effect on visual ability, color can be used to make the working environment more interesting and pleasant. For example, the colors cream, ivory and buff are "warm" psychologically. Light grey finishes are closer to neutral and are excellent for either the background or for equipment and machinery. Green and blue tints give a cool effect.

Better Housekeeping, Repair and Maintenance

Unpainted metal parts of machines, which are usually black or grey, allow dust, dirt and grease to accumulate unnoticed, covering up defects in the machine. Painting encourages students to keep machines clean and enables defects to be spotted while they are still minor.

Coding Technique

The use of color as a technique for coding various controls has met with great success. For instance, piping systems which carry dangerous contents (e.g., acetylene) would be painted yellow, fire protection systems would be painted red, and so forth. Such color coding is of value from both a safety and maintenance standpoint.

COLOR FOR ACCIDENT PREVENTION SIGNS

Color has found particular acceptance and use in accident prevention signs where uniformity in the color and design of signs is essential. ANSI Z35.1-1972, "Specifications for Accident Prevention Signs," specifies the following color combinations for industrial accident prevention signs:

Danger

- Danger — immediate and grave danger or peril. White lettering within red oval on black rectangular background in upper panel; black or red lettering on white background in lower panel.

Caution

- Caution — against lesser hazards. Yellow lettering on black background in upper panel; black lettering on yellow background in lower panel.

General Safety

- General Safety — white lettering on green background on upper panel; black or green lettering on white background on lower panel.

Fire and Emergency

- Fire and Emergency — white letters on red background in upper panel; red on white background optional for lower panel.

There are codes for other common uses:

Information

- Information — blue is used on informational signs and bulletin boards not of a safety nature.

In-Plant Vehicle Traffic

- In-Plant Vehicle Traffic — standard highway signs (ANSI D6.1-1971).

Exit Marking

- Exit Marking — red letters on white background.

RECOMMENDED COLOR STANDARD FOR MARKING HAZARDS

The following colors have been designated by the American National Standards Institute Standard Z53.1-1971, "Safety Color Code for Marking Physical Hazards," for spotlighting hazards and assisting in the visual identification of equipment and other items in the school shop. (See Appendix A for suggested visuals.)

Red

Red identifies danger, emergency stops on machines and fire protection equipment. OSHA regulations require red lights at barricades and at temporary obstructions. Red must also be used for:

1. danger signs
2. stop buttons or electrical switches used for emergency stopping of machinery
3. portable containers (including safety cans) holding flammable liquids
4. fire hydrants, pumps and sirens
5. location of fire extinguishers
6. fire exit signs
7. fire buckets or pails
8. fire alarm boxes
9. fire hose locations
10. post indicator valves for sprinkler systems
11. sprinkler piping.

Orange

Orange is used as the standard color for calling attention to dangerous parts of machines or energized equipment which may cut, crush, shock or otherwise injure, and to emphasize such hazards when enclosure doors are open or when gear, belt, or other guards around moving equipment are open or removed, exposing unguarded hazards. Examples:

1. The inside of movable guards (those which can be opened or removed) are painted orange to attract the attention of the machine operator.

2. Safety starting buttons and boxes are painted orange as a warning of the potential hazard involved and as a "hands-off" notice to unauthorized persons.
3. The edges of exposed parts of gears, pulleys, rollers, cutting devices, power jaws and similar devices are painted orange to warn against contact.
4. The insides (as a minimum) of the box door or cover of open fuse, power and electrical switch boxes are painted orange to warn of exposed live wires and electrical equipment.

Yellow

According to OSHA regulations (29 CFR 1910.144), "Yellow shall be the basic color for designating caution and for marking physical hazards such as: Striking against, stumbling, falling, tripping, and 'caught in between.' Solid yellow, yellow and black stripes, yellow and black checkers (or yellow with suitable contrasting background) should be used interchangeably, using the combination which will attract the most attention in the particular environment." Examples:

1. exposed and unguarded edges of platforms, pits and walls
2. fixtures suspended from ceilings or walls which extend into normal operating areas
3. handrails, guardrails, or top and bottom treads of stairways where caution is needed
4. lower pulley blocks and cranes
5. markings for projections, doorways, traveling conveyors, low beams and pipes, the frames of elevator ways and elevator gates
6. materials-handling equipment (or areas thereon), such as forklifts and hand trucks
7. pillars, posts or columns which might be struck
8. vertical edge of horizontally sliding pairs of fire doors.

Blue

Blue, in the railroad and other industries, is the standard color for warnings against starting, using, or moving equipment under repair or being worked upon. Blue is also used for warnings, such as painted barriers, flags, and so forth, which should be located at the power source or starting point of machinery and displayed on:

1. ovens and vats
2. tanks
3. kilns
4. boilers
5. electrical controls
6. scaffolding
7. ladders

In construction yellow (instead of blue) is used for these same purposes.

Green

Green is used as the standard color for designating safety and for showing the location of first aid equipment (other than fire-fighting equipment). It is recommended that the use of "safety green" be restricted for protection of the worker, so that the color will have value in acquainting him with the location of safety and allied devices and so that their location will come to mind readily in time of need or emergency. Examples:

1. stretchers and stretcher cabinets
2. first aid cabinets
3. first aid kits
4. respiratory containers
5. emergency showers
6. safety bulletin boards.

Purple

Purple is the standard color for designating radiation hazards, hazards which are not faced by industrial/vocational education shops.

White and Black

White, black or a combination of these are traffic and housekeeping markings. Solid white, solid black, single color striping, alternate stripes of black and white or black and white checkers should be used in accordance with local conditions. Examples:

1. dead ends of aisles or passageways
2. location and width of aisleways
3. stairways (risers, direction and border limit lines)
4. location of refuse cans
5. white corners for rooms or passageways
6. drinking fountains and food dispensing equipment locations
7. clear floor areas around first aid, firefighting or other emergency equipment.

ADVANTAGES AND LIMITATIONS OF THE SAFETY COLOR CODE

Introducing students in industrial/vocational education shops to the safety color code has two advantages. First, the students who are taught the code are absorbing each day the information it gives them about their environment, and they will react spontaneously in time of emergency. Secondly, because the safety color code has been adopted widely by industry and construction, students are using an information system in the school shop which can be applied immediately to their future workplaces.

However, instructors must keep two limitations in mind when using the standard safety color code.

1. Too many color identifications in the environment are both confusing and fatiguing. For maximum emphasis the number of markings should be kept to a minimum.
2. It is far better to eliminate a hazard than to mark it with a color warning. The code is only a supplement to a program aimed at properly guarding or, wherever possible, eliminating the hazardous condition.

QUESTIONS AND ANSWERS

1. What are four benefits derived from adequate illumination?

Any four from among the following:

a. Fatigue and eyestrain are reduced.

b. Errors are minimized.

c. Defects can be detected more readily.

d. The time necessary to determine fine details and make fine measurements is reduced.

e. Shop housekeeping is improved.

f. The social climate is improved.

2. Two important factors associated with illumination are its quality and quantity. The amount of light that produces brightness of the task and its surroundings is referred to as ______________________ __.

Quantity

3. Name the two kinds of glare.

Direct glare and reflected glare

4. What are the major classifications of lighting systems?

a. direct

b. semi-direct

c. general diffuse or direct-indirect

d. semi-indirect

e. indirect.

5. Maintenance of adequate illumination in the shop requires four tasks. What are they?

a. cleaning fixtures

b. cleaning room surfaces and windows

c. replacing worn out globes and tubes

d. repainting fixtures and room surfaces.

6. What are four advantages of using color in the shop?

a. improved visual performance

b. more pleasant shop environment

c. better housekeeping and improved repair and maintenance

d. spotlighting hazards.

7. How are the following colors used in the standard safety code: red, orange, yellow, green, white and black?

a. red — danger, emergency stops on machines, fire protection equipment

b. orange — dangerous parts of machines or energized equipment

c. yellow — caution; physical hazards

d. green — safety and first aid equipment

e. white and black — traffic and housekeeping.

8. What two limitations should be kept in mind in using the standard color safety code?

a. Because too many identifications are confusing, the number of markings should be kept to a minimum.

b. It is better to eliminate a hazard than to mark it.

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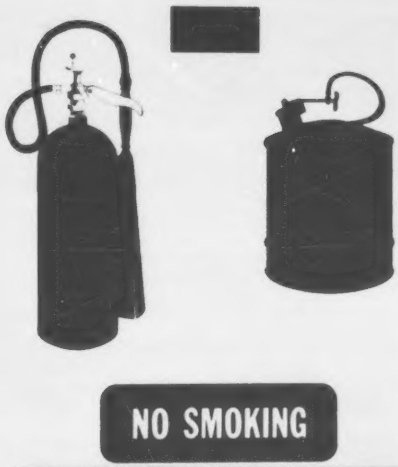
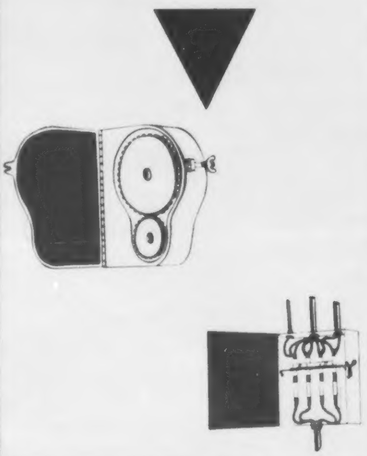
APPENDIX A

SUGGESTIONS FOR SLIDES AND FIGURES

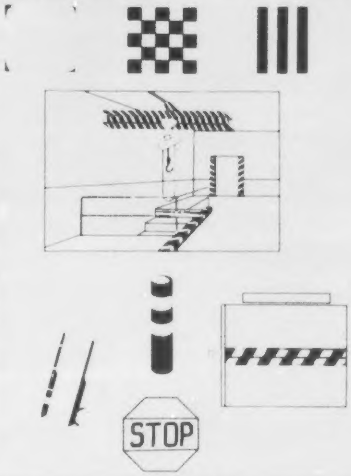
FIRE PROTECTION RED



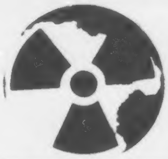
ALERT ORANGE



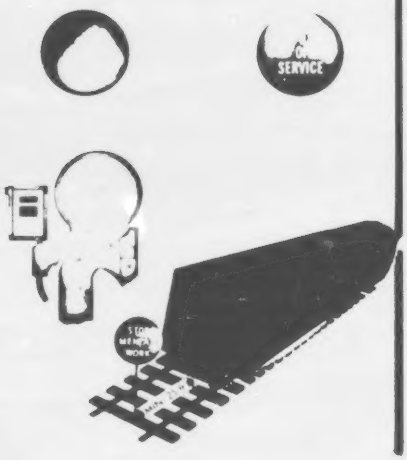
HIGH VISIBILITY YELLOW



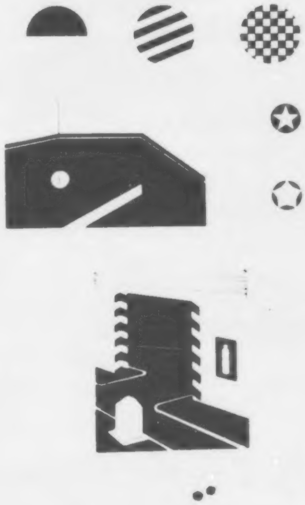
RADIATION PURPLE



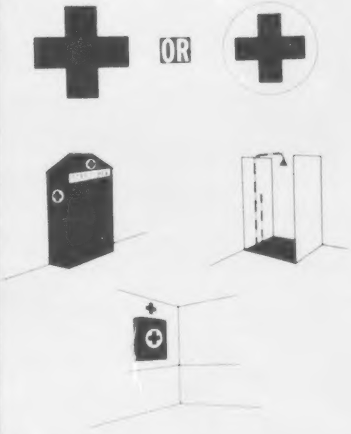
PRECAUTION BLUE


SERVICE
WORK

TRAFFIC WHITE



SAFETY GREEN



APPENDIX B

HOW WE SEE
AND
THE THEORY OF COLOR

NOTES

1. The sections on "How We See" and "Factors Affecting Seeing" are adapted from *American National Standard Practice for Industrial Lighting,* ANSI/IES RP-7-1979 (New York: Illuminating Engineering Society, 1979), pp. 8–9.

2. This section of "Visual Skills" is adapted from Ernest J. McCormick, *Human Factors Engineering,* 3rd ed. (New York: McGraw-Hill, 1970), pp. 55–60.

INTRODUCTION

This appendix deals with some of the more technical aspects of illumination and color: how we see, factors affecting seeing, the anatomy of the eye, visual skills and the theory of color.

HOW WE SEE[1]

Silhouette

In general, one sees objects in three ways: reflection, transmission and silhouette. Perception by silhouette involves detecting an object and its contour because its darker outline contrasts against lighted surroundings. Silhouette lighting is used as low-level safety lighting, where hazardous objects or obstacles are seen against lighted surroundings (protective and emergency lighting, outdoor passageways and roadways).

Transmission

Transmission involves the revealing of details through the variation and transmission of white light or the changing of color through materials that are susceptible to penetration. Transmission generally involves the inspection of translucent materials.

Reflection

By far the most common method of seeing is by reflected light, where light and dark areas or details are revealed by a difference in reflection. Highlights and shadows are actually the result of the amount of light reflected by an object which in turn helps us to perceive the world in three dimensions.

FACTORS AFFECTING SEEING

The visibility of an object is determined by size, contrast, time of viewing and brightness. Each of these factors is sufficiently dependent upon the others so that a deficiency in one may be compensated for (within limits) by augmenting one or more of the others.

Size

As size increases, visibility increases, and up to a certain point seeing becomes easier. If the size of an object is small, a person should use more light, hold the object closer to his eye or even use a magnifier.

Contrast

To be readily visible, each detail of the perceived object must differ in brightness (or color) from the surrounding background. If discrimination is dependent solely on brightness differences, visibility is at a maximum when the contrast of details with the background is the greatest. Therefore, within the limits available, the contrast between the object regarded and its immediate background should be made as high as possible. Where it is impractical to provide good contrast conditions, higher levels of illumination help compensate for poor contrast.

Time

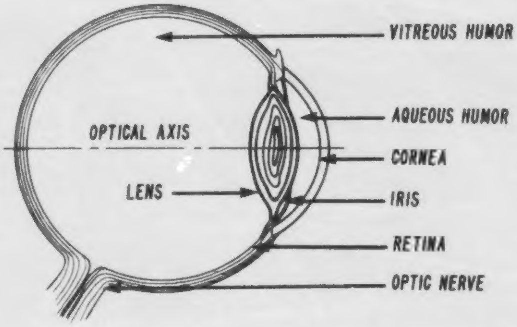
The speed with which a visual task can be performed is related to illumination, size and contrast. By increasing illumination, the time required for seeing will be shortened. Tasks of high contrast and large size generally require less time than tasks of low contrast and small size.

Brightness

Size, contrast, and to some extent time are factors inherent in the task itself. Brightness is the visibility factor that is most controllable. Within wide limits, brightness can be controlled by varying the amount and distribution of light and can to some extent compensate for deficiencies in other factors.

ANATOMY OF THE EYE

The eye, in many respects, resembles a camera. Each of its parts is essential (see Figure 22).



Adapted from *Illumination for Safety,* U.S. Department of Labor, Bulletin 297, (1967), p.3.

Cornea

The *cornea* is an outer, frontal, clear covering which admits light to the eye. It protects the eye.

Iris

The *iris* is a pigmented shutter that opens and closes in response to light intensity. It regulates the amount of light which is admitted to the eye. Two muscles in the iris change the size of the pupil.

Pupil

The *pupil* is not a black structure but simply a hole in the center of the iris. In bright light it becomes smaller in order to limit the amount of light entering the eye, and it opens wider when the amount of light is less.

Lens

The *lens* is immediately behind the iris. It is a flexible optical instrument filled with clear colorless fluid. The flexibility of the lens permits it to adjust itself to bring about proper focus on the retina.

Aqueous Humor

The *aqueous humor* is behind the cornea. It is a transparent fluid that provides a protective layer for the iris and lens.

Retina

The *retina* covers almost all of the inner surface of the eyeball. The image of an object upon the retina is reversed and inverted, just as it is in a camera. The nerve receptors on the retina, upon receiving light through the lens, set up nerve impulses which are transmitted through the optic nerve to the brain, where translation takes place.

Optic Nerve

The *optic nerve* includes all the nerve fibers in the eye. It serves as a pathway for the electrical energy from the retina to the brain.

VISUAL SKILLS[2]

The eyeballs are moved by sets of muscles that surround them so that the eyes can move in various directions. The different features of the eye make possible certain visual skills.

Visual Acuity

Accommodation

Visual Acuity – Visual acuity is the ability to perceive black and white detail at varying distances. It is largely controlled by the accommodation of the eyes. Accommodation is the adjustment of the lens of the eye to bring about proper focusing of the light rays on the retina.

Convergence

Convergence – When our visual attention is directed to a particular object, our two eyes converge on the object, accommodating to the distance so that the images of the object on the two retinas are in corresponding positions. In this way we get an impression of a single object. Convergence is controlled by muscles that surround the eyeball.

Depth Perception

Depth Perception – Depth perception, or stereopsis is an impression of depth or distance caused by the eyes seeing an object from slightly different angles. A person who does not have depth perception will be forced to judge distance or depth on the basis of cues, such as size of objects relative to each other, the apparent speed of moving objects in the distance, the relative position and relative clarity of objects.

Color Discrimination

Color Discrimination – The differentiation we make between colors is due primarily to the action of the cones of the retina.

The retina is made up of approximately 130 million rods which tend to predominate toward the outer reaches of the retina around the sides of the eyeball. They are primarily sensitive to the amount of light, with little sensitivity to differences in wave length. Accompanying the rods are approximately six to seven million cones which are more sensitive to variations in the wave lengths of light, thus giving rise to the subjective sensation of color.

Dark Adaptation

Dark Adaptation — The adaptation of the eye to different levels of brightness and darkness is brought about by two functions:

1. As we go into a darkened room, the pupil of the eye increases in size in order to admit more light to the eyes. The pupil tends to contract in bright light, in order to limit the amount of light that enters the eyes. Because this process takes a little while, as we proceed from one condition of illumination to another we may be partially blinded until this process is completed.

2. Another function that affects how well we can see as we go from the light into darkness is a physiological process in the retina in which "visual purple" is built up. Under such circumstances the cones (which are color sensitive) lose most of their sensitivity, and the rods take over our visual functions. Since in the dark our vision is dependent very largely on the rods, color discrimination is limited in the dark. The time required for complete dark adaptation is usually 30 to 40 minutes or more. The reverse adaptation from darkness to light takes place much more rapidly, usually in a matter of seconds or, at most, in a minute or two.

THEORY OF COLOR

Some substances absorb almost all of certain wave lengths and reflect only one part of the spectrum. This property gives the object its color. Thus, an object appears green because it absorbs most colors and reflects green. Black is not a color, but black objects appear so because most of the light is absorbed and little light is reflected. Yellow occupies the point of highest visibility in the spectrum. Most authorities agree that black lettering on a yellow background has the greatest legibility.

The following definitions are useful in discussing color:

Color

- *Color* (chrome, hue, shade, tint, tinge) means a property of a thing visible only in light.

Hue

- *Hue* is that attribute of a color which distinguishes it from other colors; i.e., red from yellow, blue from green, etc. It also applies to variations in a color when mixed with another color.

Tone

- *Tone* is that attribute by which a color holds a position in a dark-to-light scale, such as navy blue which differs in *tone* from light blue. *Tone* is also known as *saturation.*

Tint

Tint, a light or delicate touching with color, is also sometimes used to mean the slight alteration of a color.

Tinge

Tinge is an infusion or trace of color.

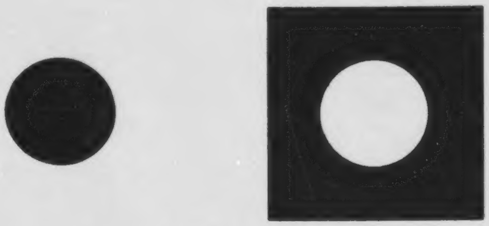
Shade

Shade has come to mean simply any color.

Irradiation

"Bright" colors appear larger than "deep" colors. Experiments have proven that yellow is seen as the "largest" of hues, followed by white, red, green, blue and black. From this it follows that signs, objects and rooms can be made to appear to expand or contract in accordance with arrangements of color brightness within the field of vision. Ceilings can be made to look higher or lower; walls, nearer or farther away; and selected forms or shapes, larger or smaller.

Instructor Note: Refer to Figure "Irradiation." If color slide is not available, use cutouts.



IRRADIATION

Reprinted from *Color in Safety*, U.S. Department of Labor, Bureau of Labor Standards, Bulletin 298 (1967), p. 3.

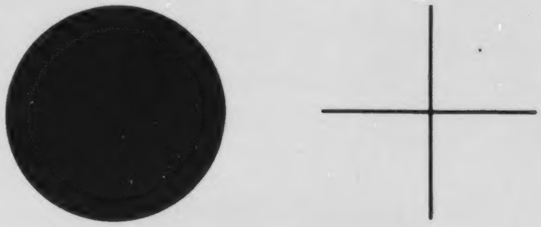
In this figure both background panels are the same size as are the two discs, but the yellow disc on the black background appears larger than the black disc on the yellow background.

Complementation

Every color has an after-image of its complement. Since a similar phenomenon is true for all colors, the proper knowledge of complementary colors will enable one to emphasize any given colored area by giving it a background of its complement.

Instructor Note: Refer to Figure "Complementation."

If you will stare at the red disc at the lower left while you count slowly to twenty and then gaze at the small cross to the right, you will see a light blue-green after-image appear.



COMPLEMENTATION

Reprinted from *Color in Safety,* U.S. Department of Labor, Bureau of Labor Standards, Bulletin 298 (1967), p. 3.

UNIT 12

FIRE PROTECTION

METHODS Lecture and Demonstration LENGTH: 60 Minutes

PURPOSE To introduce the participant to methods whereby fires in the industrial/vocational education shop can be prevented and controlled.

OBJECTIVES To familiarize participants with:

1. The fundamentals of fire
2. Common ignition sources and ways to control them
3. The classes of fires and precautions aimed at preventing each class from occurring
4. Requirements for storing flammable liquids and hazardous substances
5. Ways to limit fire spread
6. Requirements for an adequate fire system, including detection devices, sprinkler systems and portable fire extinguishers
7. Emergency procedures in case of fire.

SPECIAL TERMS

1. Fire
2. Combustion
3. Uninhibited Chain Reaction
4. Flash Point
5. Auto-Ignition Temperature
6. Flammable Liquid
7. Combustible Liquid
8. Spontaneous Ignition
9. Static Electricity
10. Bonding
11. Grounding
12. Ionization
13. Dry-Pipe
14. Wet-Pipe

INSTRUCTOR MATERIALS
Chalk Board/Chalk
35 mm Slides, Projector and Screen

TRAINEE MATERIALS Participant Outlines

UNIT 12

FIRE PROTECTION

INTRODUCTION

The last several units have been concerned with some principles of good shop planning, including the construction of safe working surfaces, maintenance of facilities and provision for adequate illumination. Two other important considerations in planning the school shop are fire protection and safe storage and handling of hazardous materials. In this unit we will examine the classes of fires, the special properties of flammable and combustible materials and the storage facilities necessary for fire protection. We will then discuss various fire protection systems: detection devices, sprinkler systems and fire extinguishers.

The potential for fires in industrial/vocational education shops is a great deal higher than many persons believe. National Fire Protection Association studies demonstrate that, in 1976 alone, 23,500 fires occurred in educational facilities, accounting for $159,700,000 in property losses. Many of these fires began in school shops.

FUNDAMENTALS OF FIRE

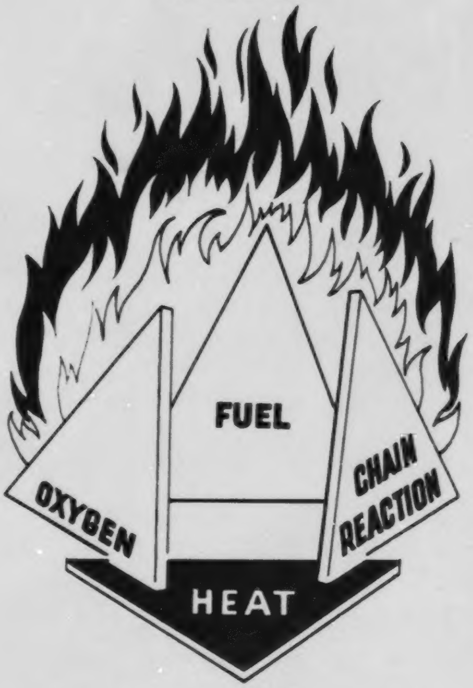
Everything necessary to start a fire is present in the industrial/vocational education shop. Fire is the combining of oxygen and fuel in proper temperature to sustain combustion. Combustion is the chemical process in which, as a result of applied heat, fuel and oxygen unite at a rapid rate, producing light and heat. To produce combustion there must be:

Fire Pyramid

- fuel
- oxygen (air)
- heat
- uninhibited chain reaction (see Figure 23).

Each of these is present in the industrial/vocational education shop.

FIRE PYRAMID



"The fire pyramid." Oxygen, heat, fuel, and chain reactions are necessary components of a fire. Speed the process and an explosion results.
Reprinted with permission from *Accident Prevention Manual for Industrial Operations,* 7th ed. (Chicago: National Safety Council, 1974), p. 1341.

Figure 23

Fuel

Fuel is usually in abundant supply from sources such as gasoline, paint, solvents, plastics, oily rags, hydrogen generated during battery charging, cleaning materials, sawdust, paper and scrap. Common chemical elements also serve as fuels: carbon, hydrogen and sulphur.

Oxygen

The oxygen necessary for a fire is in plentiful supply from the open air itself. The air we breathe generally contains 21 percent oxygen. The shop also contains oxydizing agents which support combustion (for example, iron oxides, nitric acids and nitrogen oxides).

Heat

Fuel will not burn, or the union of oxygen and fuel will not take place, until a certain temperature is reached. Various fuels ignite at various temperatures. Two terms are used in defining the temperature at which a fuel ignites: flash point and auto-ignition temperature.

Flash Point

Flash point is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid. Those liquids with the lowest flash points are the most hazardous. Flash point temperatures cannot be considered constants, for they are related to other conditions. For example, the amount of vapor that will accumulate in the air above a volatile liquid depends upon

1. vapor pressure or the relative saturation of air with the vapor
2. the surface area of the volatile liquid.

Flammable Liquids
Combustible Liquids

Flammable liquids are those with flash points below 100°F; combustible liquids are those with flash points at or above 100°F.

Auto-Ignition Temperature

Auto-ignition temperature is the lowest temperature at which a flammable gas- or vapor-air mixture will ignite from its own heat source or a contacted heat surface without the necessity of a spark or flame. Vapors and gases will ignite spontaneously at a lower temperature in oxygen than in air. The majority of vapors and gases will not self-ignite in air until they reach temperatures of about 500°F to 900°F.

Heat may be produced by friction, an electric spark, chemical action, the rays of the sun or heat from other burning materials. In the industrial/vocational education shop the source of ignition may also come in such forms as open flames, sparks, heating systems, welding, hot metal and electrical equipment.

Uninhibited Chain Reaction

The fourth side of the fire pyramid is an uninhibited chain reaction. This concept emphasizes the need for chemical reactions between the fuel and oxidizer to progress without interference.[1]

Removing One Side of Fire Pyramid

The most common way of preventing fires is by eliminating either the fuel or the heat (source of ignition). To extinguish a fire, it is necessary to remove one side of the pyramid:

1. Fuel. Remove or seal off fuel by mechanical means, or divert or shut off the flow of burning liquids or gases.

2. Oxygen. Exclude the air by smothering or by dilution.
3. Heat. Cool the burning material below its ignition point with a suitable cooling agent.
4. Chain Reaction. Interrupt the chemical chain reaction of the fire by using dry chemical or Halon extinguishing agents.[2]

Later in this unit methods of extinguishing fires will be discussed in more detail.

HEAT TRANSFER

Before we can discuss fire protection, it is necessary to understand clearly the methods of heat transmission.

Direct Contact

The most common means of spreading or propagating a fire is the direct contact of flammable or combustible material with a flame.

Conduction

Conduction is the transfer of heat from one body or object to another through an intervening conducting medium, usually a solid.

Convection

Convection is heat transmission by a circulating medium, either gas or liquid. Since heated media expand and rise, the hot gases and smoke convey heat and toxic gases to the upper floors. The more intense the fire, the greater the speed with which the smoke and heat rise. Convection of smoke, heat and toxic gases through vertical openings presents grave dangers to persons on the upper floors of buildings. Some toxic gases from fire are carbon monoxide (CO) and sulphur dioxide (SO2).

Radiation

Heat waves or rays given off by a heated body travel in all directions in straight lines until they are absorbed or reflected by another object. The amount of heat radiated from the source increases very rapidly as the temperature of the source rises. The amount of radiant heat reaching an exposed object depends upon the temperature difference between the heat source and the object and the distance between them.

Propagation of Explosions

Explosions of flammable dust usually occur in a series, with the later explosions causing the most serious damage. Fire, which may or may not cause another explosion, occurs after the initial explosion.

IGNITION SOURCES

A study of approximately 25,000 industrial fires traced the origins of these fires to the following general causes:

1. 23% electrical
2. 18% smoking
3. 10% friction
4. 8% overheated materials
5. 7% hot surfaces
6. 7% burner flames
7. 5% combustion sparks
8. 4% spontaneous ignition
9. 4% cutting and welding
10. 3% exposure
11. 3% incendiarism
12. 2% mechanical sparks
13. 2% molten substances
14. 1% chemical action
15. 1% lightning
16. 1% static sparks
17. 1% miscellaneous.

Electric Fires

Electric failures and misuse of electrical equipment are the principal causes of industrial fires. Some specific causes of such fires are electrical arcing, short circuits, overloaded circuits and equipment and substandard wiring. Proper maintenance and periodic inspection of electrical equipment and proper job training will reduce the hazards of this ignition source. Haphazard wiring, poor connections and "temporary" repairs must be brought up to standard. Fuses should be of the proper type and size. Circuit breakers should be checked to see that they have not been blocked in the closed position, which results in overloading, and to see that moving parts do not stick. The National Electrical Code, NFPA Standard No. 70, should be followed.

Smoking

Smoking and matches are the second most common cause of fire. This potential ignition source can be controlled if students are taught to follow smoking regulations and to smoke only in nonhazardous, permitted areas. Because careless disposal of ashes and matches can present problems in permitted smoking areas, proper receptacles should be provided to prevent fire in these areas. Prohibition of smoking without proper attention to education has caused fires through clandestine smoking. Where regulations permit, smoking areas should be provided and students taught why it is hazardous to smoke in prohibited areas.

Friction

Fires caused by friction usually result from hot bearings, misaligned or broken machine parts, choking or jamming of material and poorly adjusted power drives and conveyors. Friction can be eliminated by proper maintenance and lubrication and regular inspection of all mechanical equipment.

Overheated Materials and Hot Surfaces

Another cause of fire is overheated materials, the result of processes or operations that require the heating of flammable materials and liquids and ordinary combustibles. Fires caused by hot surfaces are usually the result of conduction, convection and radiation of heat from boilers, hot ducts or flues, steam pipes or electric lamps, which ignite flammable liquids and combustibles. Control of such fires requires:

1. proper clearances of combustible materials around boilers, steam pipes, etc.
2. adequate insulation and air circulation between hot surfaces and combustibles
3. proper job training and careful supervision
4. well maintained automatic temperature control devices.

Burner Flames and Combustible Sparks

Fires caused by burner flames are usually the result of improper use or poor maintenance of portable torches, boilers, driers and portable heating equipment. The sources of fires started by sparks can usually be traced to burning rubbish, engine stacks, foundry cupolas, furnaces and welding stations. Burners, stoves, furnaces, etc., should be properly adjusted and maintained, with adequate clearances from combustibles and with spark arrestors on exhaust flues or pipes. Other preventive measures include keeping open flames away from combustible materials, employing adequate ventilation and combustion safeguards, and proper design, operation and maintenance.

Spontaneous Ignition

Spontaneous ignition occurs when combustibles and oxygen in the air are heated sufficiently to begin a reaction which continues until the combustible materials reaches a temperature at which the reaction becomes self-sustaining. This temperature level is known as the ignition point or ignition temperature. Spontaneous ignition is usually the result of improper disposal of oily waste and rubbish and of deposits in ducts and flues. Control methods include:

1. Provide safe containers for all substances subject to spontaneous heating.
2. Provide for prompt and regular disposal of the contents of such containers.
3. Use nonflammable cleaning solvents.
4. Provide for regular cleaning of ducts and flues.
5. Isolate storages subject to spontaneous heating.

Cutting and Welding

Fires that occur as the result of cutting and welding operations are usually caused by sparks and hot metal landing near welding surfaces, or by defective gauges or deteriorated gas lines on the welding apparatus. Proper training of students in the recognition of hazards during cutting and welding will help reduce these ignition sources. A later unit will be devoted to safety and health considerations in welding operations.

Exposure

Fires that occur through exposure are usually caused by heat from adjoining or nearby buildings.

Incendiarism

Incendiary fires are started maliciously by employees in the industrial setting and students in the school setting or by intruders.

Mechanical Sparks

Fires caused by mechanical sparks are usually generated by metal in machines or during grinding and crushing operations. Proper care in cleaning and keeping stock free of foreign metallic pieces will prevent sparks from causing fires.

Molten Substances

Fires caused by molten substances generally are the result of molten metal released from a ruptured furnace or spilled during handling. They can be prevented by proper operation and maintenance of equipment.

Chemical Action

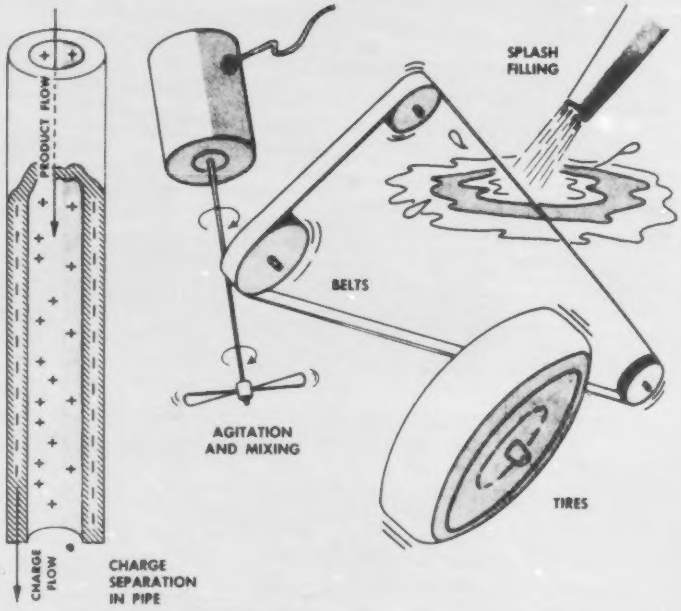
Chemical fires start when chemicals react with other chemicals or materials or when decomposition causes chemicals to be unstable. The best preventives are proper operation and careful handling and storage, particularly avoiding conditions of heat and shock.

Static Sparks

Fires from static are the result of contact and separation of materials which ignite flammable vapors, dusts and fibers. These static charges are generated on agitation and mixing equipment, belts, splash-filling of tanks, etc. They can be prevented by grounding, bonding, ionization and humidification.

STATIC ELECTRICITY[3]

Static electricity is generated by the contact and separation of dissimilar materials. For example, static electricity is generated when a fluid flows through a pipe or from an orifice into a tank. Examples of several methods of generating static electricity are shown in Figure 24.



Typical static-producing situations, including charge separation in pipe.
Reprinted with permission from *Accident Prevention Manual for Industrial Operations*, 7th ed. (Chicago: National Safety Council, 1974), p. 1290.

Figure 24

The principle hazards created by static electricity are those of fire and explosion, which are caused by spark discharges containing sufficient energy to ignite any flammable or explosive vapors, gases or dusts which are present. Students and staff may also be shocked, causing an involuntary reaction (such as falling) which may lead to injury.

Static sparks are most dangerous where flammable vapors are present in the air, such as at the outlet of a flammable liquid fill pipe, a delivery hose nozzle, near an open flammable liquid container and around a tank truck fill opening or barrel bunghole. A spark between two bodies occurs when there is not a good electrical conductive path between them. Grounding and bonding of flammable liquid containers prevent static electricity from causing a spark. Recommended Practice on Static Electricity, NFPA Standard No. 77, should be consulted for details.

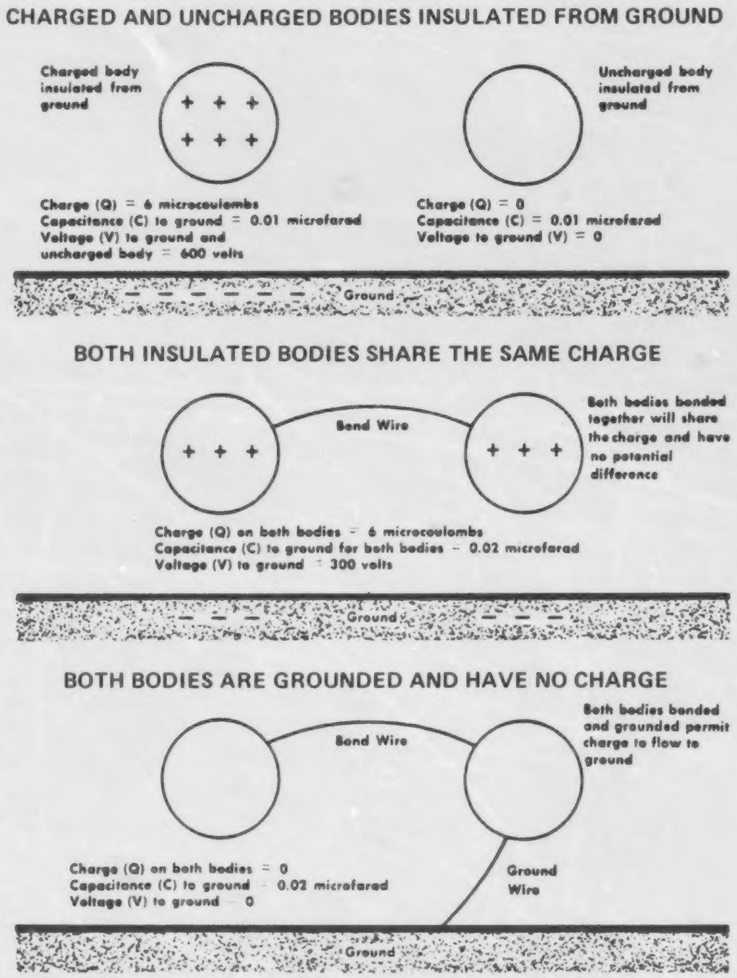
BONDING AND GROUNDING

The words "bonding" and "grounding" often have been used interchangeably because of a poor understanding of terms. The purpose of bonding is to eliminate a difference in potential *between objects*. The purpose of grounding is to eliminate a difference in potential *between an object and ground* (see Figure 25). Bonding and grounding are effective only when the bonded objects are conductive.

Although bonding will eliminate a difference in electrical potential between the objects that are bonded, it will not eliminate a difference in potential between those objects and the earth, unless one of the objects possesses a ground to earth. Therefore, bonding will not eliminate the static charge but will equalize the potential between the objects bonded so that a spark will not occur between them.

Flammable liquids are capable of building up electrical charges when they flow through piping, when they are agitated in a tank or a container, or when they are subjected to vigorous mechanical movement such as spraying or splashing. Proper bonding and grounding of the transfer system usually drains off this static charge to ground as fast as it is generated. However, rapid flow rates in transfer lines can cause very high electrical potentials on the surface of liquids, regardless of vessel grounding. Furthermore, some petroleum liquids are poor conductors of electricity, particularly the pure, refined products; even though the transfer system is properly grounded, a static charge may build up on the surface of the liquid in the receiving container. The charge accumulates because static cannot flow through the liquid to grounded metal as fast as it is being generated. The accumulated static charge can result in a static spark with sufficient energy to ignite a flammable air-vapor mixture.

BONDING AND GROUNDING


CHARGED AND UNCHARGED BODIES INSULATED FROM GROUND
Charged body insulated from ground
Uncharged body insulated from ground
+ + + + + +
Charge (Q) = 6 microcoulombs
Capacitance (C) to ground = 0.01 microfarad
Voltage (V) to ground and uncharged body = 600 volts
Charge (Q) = 0
Capacitance (C) = 0.01 microfarad
Voltage to ground (V) = 0
Ground
BOTH INSULATED BODIES SHARE THE SAME CHARGE
Bond Wire
+ + +
+ + +
Both bodies bonded together will share the charge and have no potential difference
Charge (Q) on both bodies = 6 microcoulombs
Capacitance (C) to ground for both bodies = 0.02 microfarad
Voltage (V) to ground = 300 volts
Ground
BOTH BODIES ARE GROUNDED AND HAVE NO CHARGE
Bond Wire
Both bodies bonded and grounded permit charge to flow to ground
Charge (Q) on both bodies = 0
Capacitance (C) to ground = 0.02 microfarad
Voltage (V) to ground = 0
Ground Wire
Ground

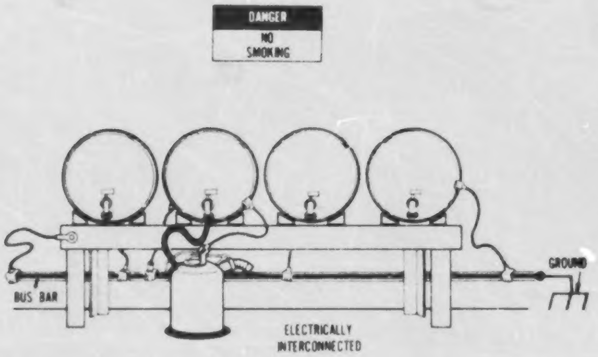
Bonding eliminates a difference of potential between objects. Grounding eliminates a difference of potential between objects and ground. Bonding and grounding apply only to conductive bodies and, when properly applied, can be depended upon to remove the charge.

Reprinted with permission from *Accident Prevention Manual for Industrial Operations,* 7th ed. (Chicago: National Safety Council, 1974), p. 1292.

Figure 25

This high static charge is usually controlled by reducing the flow rates, avoiding violent splashing with side-flow fill lines and using relaxation time.

When flammable liquids are transferred from one container to another, they must be effectively bonded and grounded. This practice prevents electrical discharge (sparks) from the accumulation of static charge because of the transfer process.



Drums grounded and bonded to receiving container.
From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 78.

Flat moving belts are sources of static electricity unless they are made of a conductive material or coated with a conductive belt-dressing compound designed to prevent the accumulation of static charges. However, V-belts usually do not create sufficient static charge to cause concern. Nonconductive materials passing through or over rolls also creates charges of static electricity.

Bonding and grounding systems should be checked regularly for electrical continuity.

IONIZATION AND CONTROLLING HUMIDITY

In addition to bonding and grounding, there are two other ways that separated charges of static electricity can be recombined before sparking potentials build up.

Ionization

The surrounding environment can be ionized. If the air in the immediate area is ionized with a charged body, a conducting path will be provided. Air can be ionized by using high voltage or radioactive static eliminators.

Control of Humidity

The humidity of the air can be controlled. Keeping the relative humidity in the area above 60 percent will condense enough moisture on the surface of the objects to allow static charges to dissipate.

CLASSES OF FIRES

Up to this point we have been discussing the causes of fires. Now we will examine the classes of fires. The National Fire Protection Association (NFPA) has defined four general classifications.

CLASS A FIRES: ORDINARY COMBUSTIBLE MATERIALS

Class A fires, sometimes called "surface burning fires," occur in ordinary combustible materials (e.g., wood, cellulose, paper, cloth, excelsior, rubber). Class A fires are extinguished by bringing the materials below their ignition temperature with the quenching and cooling effects of water. Under certain circumstances, these fires may be extinguished by the blanketing and smothering effects of dry chemical and carbon dioxide fire extinguishers.

Precautions:

Because ordinary combustible materials serve as fuel for fire, several precautions are necessary:

Provide Adequate Disposal

1. Provide a program of adequate disposal of all combustible wastes and rubbish designed specifically for the operations or processes involved.

Provide Regular Inspection

2. Provide for regular inspection of the waste storage area.

Provide Internal Housekeeping Program

3. Provide a program of internal housekeeping which will prevent any accumulation of waste and which will result in safe, clean work areas.

Provide External Housekeeping Program

4. Provide a program of external housekeeping to prevent accumulation of waste, brush or high grass around buildings.

Several combustible substances deserve special mention: dusts, plastics, textiles, waste materials and cleaning supplies.

Dusts

Most finely divided combustible materials in air present a serious hazard. Sawdust and coal dust are examples of combustible dusts. Deposits of combustible dust on floors, beams, machines, etc., are subject to flash fires, and dust suspended in air can explode violently. Prevention or removal of dust accumulation on structural members, walls and ceilings is a necessary procedure. Precautions are:

Precautions:

Provide Local Exhaust Systems

1. Where possible, provide local exhaust systems for dust collection.

Provide Frequent Vacuum Cleaning

2. Provide a program for frequent vacuum cleaning of structural members, ceilings and walls. The vacuum cleaning equipment should be explosion proof.

Control Accumulation at Ignition Sources

3. Remove or control the accumulation of hazardous dust at all ignition sources.

Plastics

Burning plastics (e.g., nitrocellulose, polystyrene, cellulose, rayon and polyvinyl chloride) are particularly dangerous because they produce large amounts of smoke and because their fumes are extremely toxic. Special care should be taken to keep plastics away from ignition sources.

Textiles

Some textiles (e.g., rayon, cellulose fibers, cotton textiles) are highly flammable and characterized by a high rate of flame spread. Though flame retardant treatments help to slow down flame spread, such treatments may be washed out after a few launderings. Students must be cautioned to keep clothing away from ignition sources and, where necessary, to wear aprons.

Combustible Waste Materials

Combustible waste materials, such as oily shop rags or paint rags, must be stored in covered metal containers and disposed of daily.

Combustible Cleaning Materials

The materials used for cleaning also can create hazards. All oily mops must be stored in closed approved metal containers. Combustible sweeping compounds, such as oil-treated sawdust, can be a fire hazard. Floor coatings containing solvents with low flash points can be dangerous, especially near sources of ignition.

CLASS B FIRES: FLAMMABLE LIQUIDS, GASES AND GREASES

Class B fires are fires in flammable liquids, gases and greases. Class B fires are most successfully extinguished by limiting the amount of air which supports combustion. Fire extinguishers of the dry chemical, carbon dioxide, foam and halogenated hydrocarbon agent types are recommended for this class of fire. Solid streams of water are likely to spread the fire, but under certain circumstances water fog nozzles prove effective.

Flammable Liquids
100°F = 37.8°C

Flammable liquids are those with flash points below 100°F. Flammable liquids are hazardous because of their ease of ignition (low flash point), flammable range and burning intensity. The degree of danger is determined largely by the flash point of the liquid, the concentration of vapors in the air and the possibility of a source of ignition at or above a temperature sufficient to cause the mixture to burst into flame. Flammable liquids vaporize and form flammable mixtures when in open containers, when leaks or spills occur or when heated. Gasoline, ethyl alcohol, benzene, turpentine and naphtha are examples of flammable liquids. Fluid commodities containing flammable liquids (e.g., paints, varnishes, cleaning solutions) should be considered flammable liquids and classed according to the flash point of the mixture.

Combustible Liquids
100°F = 37.8°C

Combustible liquids are those having flash points at or above 100°F. They are usually safe to handle and to work with at normal temperatures, but these liquids should not be heated. Lube oils, kerosene, cresols, benzyl alcohol, cooking oil, mineral spirits and palm oil are examples of combustible liquids.

140°F = 60°C
200°F = 93.3°C

The following chart classifies some common products according to their flash points. Though not indicated on the chart, Class III combustibles are further subdivided into IIIA, those with flash points between 140°F and 200°F, and IIIB, those with flash points at or above 200°F.

73°F = 22.8°C

100°F = 37.8°C

140°F = 60°C

CLASSIFICATION OF SOME TYPICAL FLAMMABLE AND COMBUSTIBLE PRODUCTS

	Class	FLAMMABLES	Flash Point	Boiling Point
	A	Gasoline (some) Pentane	Lower than 73°F	Lower than 100°F
I	B	Acetone Denatured Alcohol Gasoline (some) Naphtha, VM and P Toluene	Lower than 73°F	At or Above 100°F
	C	Xylene	At or Above 73°F	
II		COMBUSTIBLES Kerosene Mineral Spirits Naphtha Stoddard Solvent	At or Above 100°F	
III		Asphalt Brake Fluid Fuel Oil No 4 Fuel Oil No 5 Fuel Oil No 6	At or Above 140°F	

From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 78.

Because of their low flash point and low ignition temperatures, flammable liquids are dangerous and require the following precautions:

	Precautions:
1. When possible, avoid the use of highly flammable liquids by using in their place nontoxic and nonflammable (or less flammable) liquids. For example, benzene can be replaced by toluene in most lacquers, synthetic-rubber solutions and paint removers.	Avoid Using Highly Flammable Liquids
2. Keep flammable liquids in approved fire resistant safety containers, never in glass containers. Keep all flammable liquids in closed containers when not in use.	Keep Flammable Liquids in Closed Safety Containers
3. Limit the amount of flammable liquids in the shop area to that needed for one day.	Limit Amount of Flammable Liquids in Work Area
4. Provide safe operating procedures, including local exhaust systems, for all processes.	Follow Safe Operating Procedures
5. Remove or control all ignition sources such as static electricity, smoking and open flames.	Control Ignition Sources
6. Provide for adequate clearances between flammable liquid containers or safety cans and any heat sources.	Provide Adequate Clearances
7. Provide adequate ventilation for all operations involving the use or storage of flammable liquids.	Provide Adequate Ventilation
8. Anticipate flammable liquid spills and provide means to control and limit spillage, as well as suitable absorptive materials for use in cleaning up spills. Clean up promptly all spills of flammable or combustible liquids.	Control Spills
9. Make sure that the connections on all drums containing flammable and combustible liquids are vapor and heat tight.	Make Sure Connections are Tight
10. Always use and handle flammable liquids with extreme caution, no matter how familiar they are.	Handle Flammable Liquids with Caution
11. Store large amounts of flammable liquids in a separate fire resistant building or vault, which conforms to the recognized standards. Storage tanks should be properly vented and supported by masonry or, in diked areas, by poured concrete supports.	Store Flammable Liquids Safely

The storage of flammable and combustible liquids is a subject which will be dealt with in length later in this unit.

Flammable Gases

The hazards of flammable gases are generally the same as those of flammable liquids, except that commercial gases are usually in compressed gas cylinders. Flammable compressed gases usually burn with a greater intensity than exposed flammable liquids. Acetylene, propane, hydrogen, natural gas and butane are examples of flammable gases. Their safe use and storage will be discussed in the unit on welding.

CLASS C FIRES: ELECTRICAL EQUIPMENT

Class C fires occur in electrical equipment and call for such nonconducting extinguishing agents as dry chemical, carbon dioxide and compressed gas. Fire prevention and protection for Class C fires will be discussed in the unit on electricity.

CLASS D FIRES: COMBUSTIBLE METALS

Class D fires occur in combustible metals such as magnesium, potassium, zirconium, lithium, sodium, powdered aluminum, zinc and titanium. Special extinguishing agents and methods are used, such as graphite base types and sand. Precautions for combustible metals include:

Precautions:

Provide Frequent Collection

1. Provide for frequent collection of combustible metal chips and shavings.

Keep Oil or Grease Away

2. Prevent any presence of oil or grease near or in finely divided particles of combustible metals.

Provide Safe Storage

3. Provide covered, plainly labeled, clean, dry steel containers for combustible metal particles which are to be salvaged. Store them in an isolated storage yard or at a safe distance from all buildings.

FIRE PROTECTION REQUIREMENTS FOR STORING HAZARDOUS MATERIALS

All four classes of fires can and do occur in the industrial/vocational education shop. Class D fires are a particular concern because flammable liquids and hazardous substances are necessary to many shop operations. Therefore, special attention must be paid to fire protection requirements for storing flammable and combustible materials. In this section we will discuss the requirements for storage containers, cabinets and rooms.

STORAGE CONTAINERS

The National Fire Protection Association (NFPA) publishes standards which govern fire protection in educational institutions. The NFPA code states that the storage of flammable liquids shall be limited to that required for maintenance, demonstration, treatment and laboratory work. The code establishes the following storage provisions for flammable liquids:

1. No container for Class I or Class II liquids shall exceed a capacity of one gallon, except that safety cans can be of two gallons capacity.

1 gallon = 3.8 liters
2 gallons = 7.6 liters

2. Not more than ten gallons of Class I and Class II liquids combined shall be stored outside of a storage cabinet or storage room, except in safety cans.

10 gallons = 37.9 liters

3. Not more than 25 gallons of Class I and Class II liquids combined shall be stored in safety cans outside of a storage room or storage cabinet.

25 gallons = 94.7 liters

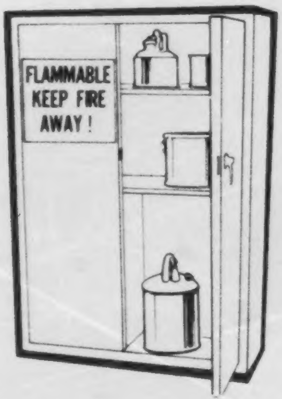
4. Not more than 60 gallons of Class IIIA liquids shall be stored outside of a storage room or storage cabinet.

60 gallons = 227.1 liters

5. Quantities of flammable and combustible liquids in excess of those set forth in this section shall be stored in an inside storage room or storage cabinet.

STORAGE CABINETS

Special cabinets are available for storing flammable and combustible liquids in the school shop. All such cabinets must be clearly labelled "Flammable—Keep Fire Away."



From *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, February 1979), p. 79.

According to the NFPA, storage cabinets must be designed so that the internal temperature does not exceed 325°F when subjected to a ten-minute fire test using the standard time-temperature curve specified by the NFPA.

325°F = 162.8°C

Metal Cabinet

1-1/2" = 38 mm.

2" = 5 cm.

For a metal cabinet, the code requires that the bottom, top, door and sides be at least No. 18 gauge sheet iron and double-walled with at least 1-1/2 inch air space between the walls. Joints must be made tight by such effective means as riveting or welding. Doors must have three-point locks, and the door sill must be raised at least two inches above the bottom of the cabinet.

Wooden Cabinets

1" = 2.5 cm.

The NFPA code also allows the use of wooden cabinets if they are properly constructed. Tests indicate that wooden cabinets can be at least as effective, and in many cases better, than metal cabinets. The NFPA specifies that a wood cabinet used for storing flammable liquids must have a bottom, sides and top constructed of an approved grade of plywood at least one inch thick. Joints must be rabbeted and fastened in two directions with flathead wood screws.

Storage Limits

60 gallons = 227 liters
120 gallons = 454 liters

The NFPA code specifies that not more than 60 gallons of flammable or 120 gallons of combustible liquids may be stored in a storage cabinet. Not more than three such cabinets may be located in a single fire area.

Exhaust Systems

Storage cabinets provide a convenient method for storing flammable and toxic chemicals when a central storage facility is not available. They are equipped with locks and provide excellent security in school situations. They also are equipped with pipe connections, which facilitate the connection of the cabinets to a mechanical exhaust system. The cabinets should be exhausted to prevent the accumulation of toxic or explosive chemical vapors. One manufacturer of storage cabinets for flammable liquids recommends that they be exhausted at a rate of twenty cubic feet per minute (cfm).

STORAGE ROOMS

Because in most educational institutions both flammable and nonflammable materials will be stored in the same area, storage rooms should be built to conform with NFPA codes for storage of flammable liquids. Storage rooms in the industrial/vocational education school should not have an opening that communicates with the public portion of the building. The NFPA code requires that:

4" = 10 cm.

1. the floor in the storage room be at least four inches lower than the surrounding floors or that there be a noncombustible, liquid-tight raised sill or ramp at least four inches high between the storage area and adjacent rooms or buildings

2. all doors be approved, self-closing fire doors
3. the room be liquid-tight where the walls join the floor.

The following table shows the quantities of flammable liquids which may be stored in rooms of various sizes. Note that rooms with separate fire protection systems are allowed far greater quantities of flammable liquids.

STORAGE IN INSIDE ROOMS

Fire protection* provided	Fire resistance	Maximum size	Total allowable quantities (gals./sq. ft. floor area)
Yes	2 hours	500 sq. ft.	10
No	2 hours	500 sq. ft.	4
Yes	1 hour	150 sq. ft.	5
No	1 hour	150 sq. ft.	2

500 sq. ft. = 46.5 sq. m.

150 sq. ft. = 13.9 sq. m.

*Fire protection system shall be sprinkler, water spray, carbon dioxide, dry chemical, halon or other approved system.

Reprinted with permission from NFPA 30, Flammable Liquids Code, *National Fire Codes,* 1979.

Table 10 shows the maximum number of gallons that may be stored on various indoor storage levels. Note that those liquids classed as A, B and C all are flammable, and Class II and III liquids are combustible.

Containers with capacities of more than 30 gallons of flammable liquid should not be stored one upon the other. Large containers should be stored on or near the floor. The higher shelves should not be higher than an average-sized person comfortably can reach while standing on the floor. Only smaller containers should be stored on the higher shelves.

Containers
30 gallons = 113.6 liters

OSHA regulations require that there be one clear aisle at least three feet wide and that lights in the storage area be explosion-proof.

Aisle
3' = 9 m.
Lights

The floors in storage rooms should be constructed out of material that is resistant to chemicals and readily cleaned. All electrical outlets and equipment must be well grounded. The room should be kept cool, but not cold enough to freeze the reagents stored in it.

Floors
Electrical Outlets and Equipment
Temperature

Table 10

INDOOR CONTAINER STORAGE

Class liquid	Storage level	Protected storage maximum per pile Gallons	Unprotected storage maximum per pile Gallons
A	Ground and upper floors.	2,750 (50)	660 (12)
	Basement.	Not permitted	Not permitted
B	Ground and upper floors.	5,500 (100)	1,375 (25)
	Basement.	Not permitted	Not permitted
C	Ground and upper floors.	16,500 (300)	4,125 (75)
	Basement.	Not permitted	Not permitted
II	Ground and upper floors.	16,500 (300)	4,125 (75)
	Basement.	5,500 (100)	Not permitted
III	Ground and upper floors.	55,000 (1,000)	13,750 (250)
	Basement.	8,250 (450)	Not permitted

Note 1: When 2 or more classes of materials are stored in a single pile, the maximum gallonage permitted in that pile shall be the smallest of the 2 or more separate maximum gallonages.

Note 2: Aisles shall be provided so that no container is more than 12 ft. from an aisle. Main aisles shall be at least 3 ft. wide and side aisles at least 4 ft. wide.

Note 3: Each pile shall be separated from each other by at least 4 ft.

(Numbers in parentheses indicate corresponding number of 55-gal. drums.)

From *General Industry OSHA Safety and Health Standards (29 CFR 1910.106)*, U.S. Department of Labor, November 1978, p. 145.

Ventilation Systems

All inside storage rooms must be equipped with either a gravity or a mechanical exhaust system to remove hazardous vapors. If flammable liquids are stored, mechanical exhaust ventilation should be used.

1' = 30 cm.

The exhaust duct should be located near the floor level (one foot above). Both the exhaust and inlet air openings should be arranged to provide air movements across all portions of the floor to prevent accumulation of flammable vapors. The NFPA code requires that the exhaust system be capable of completely changing the air within the storage room at least six times each hour. As a rule of thumb, the ventilation system should be capable of removing 10,000 cubic feet of air for every gallon of liquid vaporized.

Fire Extinguisher
10' = 3 m.

At least one fire extinguisher having a rating of at least 12-B units must be located outside of, but not more than ten feet from, the door opening into any room used for storage. Where flammable and combustible liquids are stored outside of a storage room but still inside a building, at least one portable fire extinguisher with a rating of at least 12-B units must be located not less than ten feet or more than 25 feet from the storage area.

25' = 7.6 m.

Open flames and smoking must not be permitted in flammable or combustible liquid storage areas.

Both storage cabinets and storage rooms must provide for two other considerations related directly to fire protection, security and chemical exposure protection.

Security

In addition to locking cabinets and storage rooms, security requires that a system be devised which accounts carefully for hazardous materials. Not only must such a system provide an inventory for items in storage, but also instructors must keep a record of

- *what* materials were removed
- *by whom*
- *for what purpose*
- *at what time.*

Careful recordkeeping is mandatory, both for fire protection and as part of the broader shop safety and health program.

Chemical Exposure Protection

Controlling *what* chemicals are stored and *how* they are stored will result in chemical exposure protection.

Some chemicals are incompatible and may form a violent reaction if they come into contact with one another. For example, strong oxidizing materials should not be stored next to organic materials, and flammable solvents should not be stored next to acids. This does not mean that incompatible materials have to be stored in another room or cabinet. They can be stored on another shelf or on the other side of the room. The appendix to this unit lists some examples of incompatible chemicals.

Ventilation is an important part of chemical exposure protection and, as stated above, is required in storage rooms and cabinets.

OUTDOOR STORAGE

If flammable and combustible liquids are stored outside, the area should be graded to divert possible spills away from buildings. The storage area should be kept free of debris and weeds and protected from tampering or trespassing. Smoking must be prohibited. Table 11 shows the limits on outdoor container storage.

Gasoline Storage

Special regulations apply to outdoor gasoline storage. Instructors will need to contact appropriate local and state authorities to see under what conditions, if any, storage in excess of 60 gallons is permitted.

Table 11

OUTDOOR CONTAINER STORAGE

1 Class	2 Maximum per pile (see note 1)	3 Distance between piles (see note 2)	4 Distance to property line that can be built upon (see notes 3 and 4)	5 Distance to street, alley public way (see note 4)
	gal.	ft.	ft.	ft.
IA	1,100	5	20	10
IB.	2,200	5	20	10
IC.	4,400	5	20	10
II	8,800	5	10	5
III	22,000	5	10	5

Note 1: When 2 or more classes of materials are stored in a signle pile, the maximum gallonage in that pile shall be the smallest of the 2 or more sepparate gallonages.

Note 2: Within 200 ft. of each container, there shall be a 12-ft. wide access way to permit approach of fire control apparatus.

Note 3: The distances listed apply to properties that have protection for exposures as defined. If there are exposures, and such protection for exposures does not exist, the distances in column 4 shall be doubted.

Note 4: When total quantity stored does not exceed 40 percent of maximum per pile, the distances in columns 4 and 5 may be reduced 50 percent, but not less than 3 ft.

1,100 gallons = 4,164 liters
2,200 gallons = 8,328 liters
4,400 gallons = 16,656 liters
8,800 gallons = 33,312 liters
22,000 gallons = 83,279 liters

200′ = 61 m.
12′ = 3.7 m.
3′ = .9 m.

5′ = 1.5 m.

20′ = 6 m.
10′ = 3 m.

10′ = 3 m.
5′ = 1.5 m.

From *General Industry OSHA Safety and Health Standards (29 CFR 1910.106)*, U.S. Department of Labor, November 1978, p. 146.

LIMITING FIRE SPREAD[4]

Should a fire occur in the school shop, its spread must be limited if its potential for damage is to be reduced. Several structural devices help retard the spread of fire.

Fire Walls

A fire wall is made of noncombustible materials, usually brick or block, which will not burn through nor conduct enough heat through the wall to start a fire on the other side. The length of time a fire wall will resist fire spread may vary from one hour to four hours, depending on the type of construction. Because it is usually self-supporting, a fire wall will remain standing even after the building collapses. Properly used, fire walls divide a building into separate fire areas.

Fire Doors

Although they are necessary openings in a fire wall, fire doors do not offer the protection of a solid fire wall and should be held to a minimum. Standard fire doors may be clad in steel or sheet metal with wooden or noncombustible cores, or they may be hollow metal doors. The length of time each door will protect an opening varies from 45 minutes to three hours under standard testing methods. All fire doors should be hung in noncombustible frames. The three most common kinds of fire doors are swinging, horizontal sliding and vertical sliding.

Fire doors should not be hooked in the open position. This practice destroys the protective function of the fire door.

Fire Dampers

Air ducts can be a means of conveying hot fire gases and smoke throughout a building. To prevent this, fire dampers should be installed in all ducts that penetrate fire walls and in branch lines to other fire areas. A detection system should be used to stop all fans operating in the duct work when smoke or high temperatures are detected. Fire dampers and detection systems should be installed in accordance with recognized NFPA standards.

FIRE PROTECTION SYSTEM

An adequate fire detector and/or suppression system is one of the best investments a school can make. Once installed, it must be supervised by a qualified individual and tested and inspected regularly. A good system will provide:

1. detection devices in all hazardous and concealed areas, to detect fire automatically and sound the alarm
2. manual trip boxes at all exits and other appropriate locations

3. horns or bells throughout the building to sound the alarm
4. alarm signals which give the location of the fire and are transmitted automatically to fire department alarm headquarters or to a central control station which relays the alarm to the fire department
5. a water-flow alarm which sounds when the automatic sprinkler system is activated
6. an automatic sprinkler system supplemented where necessary by special systems to control specific hazards
7. portable fire extinguishers to act as a first line of defense
8. a regular inspection and maintenance program to keep the system in proper operating condition.

FIRE DETECTION DEVICES[5]

Fire detection devices are of four main kinds. Each detects fire at a distinct stage.

1. ionization—incipient stage
2. photoelectric—smoldering stage
3. infrared—flame stage
4. thermal—heat stage.

Ionization Detectors

Ionization detectors respond to the combustion particles produced in the incipient stage. These particles, too small to be visible, are created by chemical decomposition and are generated before smoke or flame is visible and before significant heat develops. When the combustion particles rise to the ceiling, the ionization detector sounds an alarm.

Photoelectric Detectors

When the fire goes beyond the incipient to the smoldering stage, the combustion particles increase in number and become visible as smoke. Photoelectric detectors (commonly called smoke detectors) respond to this smoke, sound the alarm and shut off air flow in ducts.

Infrared Detectors

As the smoldering stage continues, the point of ignition occurs and flames start. The fire has now progressed to the third stage, the flame stage, where the smoke level decreases and the heat level increases. Infrared detectors pick up the infrared energy which is produced.

Thermal Detectors

At the final stage, the heat stage, large amounts of heat, flame, smoke and toxic gases are produced. Thermal detectors respond to this heat energy. There are two general types of thermal detectors: fixed temperature devices and rate of rise detectors.

Thermostats are the most frequently used fixed temperature detectors. The bimetallic thermostat utilizes the difference in coefficients of thermal expansion of two metals, which laminate into a single strip that bends when heated, closing the electrical contacts.

In the rate of rise system, a rapid rise in temperature heats the air in a tubing system or air chamber. This rise in pressure trips the device and sounds the alarm. If the temperature rises slowly, the pressure bleeds off through a compensating port.

AUTOMATIC SPRINKLER SYSTEMS

After a fire is detected, it must be extinguished. Automatic sprinklers are the most versatile and dependable form of fire protection available. Since their initial use in industrial plants around 1850, they have been refined and improved so that most fire protection engineers consider them the most important fire fighting equipment.

Sprinkler

A sprinkler system is an integrated system of underground and overhead piping which includes a suitable water supply, a controlling valve and a device for actuating an alarm when the system is in operation. It is usually activated by heat from a fire and discharges water over the fire area. In Standard 13 of the National Fire Code, the NFPA defines five systems, of which only two are likely to be used in the industrial/vocational education shop.

Wet-Pipe System

According to the NFPA, wet-pipe is "a system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by a fire." Antifreeze is necessary if portions of the system are subjected to freezing temperatures.

Dry-Pipe System

The dry-pipe system is defined as one "employing sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which as from the opening of sprinklers permits the water pressure to open a valve known as the 'dry-pipe valve.' The water then flows into the piping system and out the opened sprinklers."

Because it is slower to put water on the fire, the dry-pipe system should be installed only where a wet-pipe system is not practical (for example, in rooms or buildings which cannot be properly heated). However, an approved dry-pipe system is far preferable to shutting off the water supply entirely during cold weather.

Temperature Ratings

Sprinklers should be selected on the basis of occupancy and temperature rating. Ratings are based on standardized tests in which a sprinkler head is immersed in a liquid the temperature of which is raised until the head operates. The maximum room temperature at ceiling level under normal working conditions determines the sprinkler head rating to use.

135–170°F = 57.2–76.6°C
100°F = 37.7°C
175–225°F = 79.4–107.2°C
150°F = 65.6°C
250- 300°F = 121.1–148.8°C
325–375°F = 162.7–190.5°C
400–475°F = 204.4–246.1°C
500–575°F = 260°–301.7°C

Rating	Operating Temperature (F)	Color	Maximum Ceiling Temperature (F)
Ordinary	135-170	uncolored*	100
Intermediate	175-225	white*	150
High	250-300	blue	225
Extra high	325-375	red	300
Very extra high	400-475	green	375
Ultra high	500-575	orange	475

*The 135°F sprinklers of some manufacturers are half black and half uncolored. The 175°F sprinklers of the same manufacturers are yellow.

Reprinted with permission from NFPA 13, Sprinkler Systems, *National Fire Codes,* 1979.

Maintenance

Dependable sprinkler protection requires systematic maintenance and inspection. NFPA 13A, Care and Maintenance of Sprinkler Systems, gives specific maintenance requirements, including inspection of control valves, testing water flow and reading water and air pressure gauges. Because 35 percent of all sprinkler system failures are caused by closed valves, it is imperative that controlling valves be kept open and water supplies maintained in service.

The local fire department should be familiar with the automatic sprinkler equipment: its location, the arrangement of control valves, connections for fire department use and the extent of protection the system offers. Such thorough knowledge can save precious minutes and prevent faulty use in the event of a fire.

SPECIAL SYSTEMS

In addition and as a supplement to automatic sprinkler systems, there are several methods of fire control which can be installed to control specific hazards. In the industrial/vocational education setting these methods would be installed where water is not an acceptable extinguishing agent.

Foam

NFPA II, Standard for Foam Extinguishing Systems, defines foam as an "aggregate of tiny gas-filled or air-filled bubbles, lighter than the lightest oils." When applied, it forms "a coherent floating blanket on flammable and combustible liquids lighter than water and prevents or extinguishes fire by excluding air and cooling the fuel." It is used primarily for the protection of flammable liquid storage areas and tanks. The air (mechanical) foam has replaced chemical foam, which is now considered obsolete. It consists of bubbles of air produced when air and water are mechanically agitated with a foam-making agent.

Dry Chemical

According to NFPA 17, Dry Chemical Extinguishing Systems, dry chemical is a "finely divided powder, usually sodium bicarbonate, with additives to prevent caking and to increase flowability." It is widely used to extinguish the rapidly spreading surface of fire typical of flammable liquids. Because it is electrically nonconducting, it is often used on fires involving electrically energized equipment. It also can be used on ordinary combustibles when the fire is of a surface nature and where rapid flame knockdown is useful.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless, electrically nonconductive inert gas which "extinguishes fire by reducing the concentration of oxygen and/or the gaseous phase of the fuel in the air to the point where combustion stops" (NFPA 12, Carbon Dioxide Extinguishing Systems). It is used to protect gaseous and liquid flammable processes and materials, engines using gasoline and other flammable fuels, electrical equipment, ordinary combustibles and hazardous solids. Because the CO_2 concentration dilutes the oxygen in the air, this system may create an atmosphere that will not sustain life. The area must be thoroughly ventilated after the fire is extinguished.

Water Spray

Water spray systems use what is called wet water, water to which an approved wetting agent has been added, discharged from a device capable of separating the water into spray. Adding a wetting agent reduces the surface tension of the water and increases its penetrating, spreading and/or its emulsifying ability. According to NFPA 15, Water Spray Systems, such systems are particularly effective on fires involving flammable liquids, combustible solids and electrical equipment.

PORTABLE FIRE EXTINGUISHERS[6]

Portable fire extinguishers are the first line of defense in coping with fires of limited size. They are needed in the industrial/vocational education setting even when the shop is equipped with automatic sprinklers or other fixed protection devices. The National Safety Council lists six requirements for effective portable extinguishers.[7] They must be:

1. a reliable type
2. the right type for each class of fire that may occur in the area
3. in sufficient quantity to protect against the exposure in the area
4. located where they are readily accessible for immediate use
5. maintained in perfect operating condition, inspected frequently, checked against tampering and recharged as required
6. operable by the persons who are in the area, who can find them and who are trained to use them effectively and promptly.

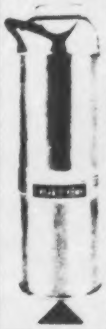
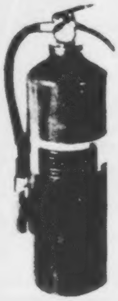
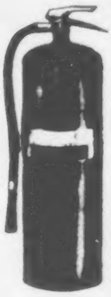
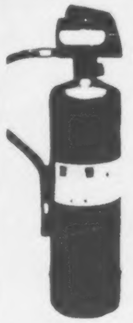
TYPES OF PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers can be divided into three basic categories: water, gaseous and dry chemical. A dry powder type is available for Class D fires. Units are classified with a letter designation—A, B, C or D or a combination—to show which classes of fire they can combat effectively (see Figure 26). Class A and B units also have a numerical rating that indicates their approximate extinguishing potential. Table 13 in the Appendix contains a complete list of extinguisher characteristics: extinguishing agents, method of operation, capacity, etc.

1. Water Types

Perhaps the most common portable fire extinguisher is the 2-1/2 gallon pressurized water unit, recommended for Class A hazards. This unit requires little skill to operate and has a long discharge time—usually about one minute—so that the inexperienced user

GUIDE TO PORTABLE FIRE EXTINGUISHERS

Class of fire	A		A/B	B/C				A/B/C			D
Type of unit	Water types		AFFF Foam	Carbon dioxide	Dry chemical types		Halon 1211	Multipurpose dry chemical		Halon 1211	Dry powder
	STORED PRESSURE	PUMP TANK	STORED PRESSURE	SELF EXPELLING	STORED PRESSURE	CARTRIDGE OPERATED	STORED PRESSURE	STORED PRESSURE	CARTRIDGE OPERATED	STORED PRESSURE	CARTRIDGE OPERATED
											
Sizes available	2½ Gal.	2½ and 5 Gal.	2½ Gal.	5-20 lb.	2½-30 lb.	4-30 lb.	2 to 22 lb.	2½-30 lb.	5-30 lb.	9 to 22 lb.	30 lb.
Approximate horizontal range	30 to 40 ft.	30 to 40 ft.	20 to 25 ft.	3-8 ft.	10-15 ft.	10-20 ft.	10 to 16 ft.	10-15 ft.	10-20 ft.	14 to 16 ft.	5 ft.
Approximate discharge time	1 Min.	1 to 3 Min.	50 Sec.	8-15 Sec.	8-25 Sec.	8-25 Sec.	8 to 18 Sec.	8-25 Sec.	8-25 Sec.	10 to 18 Sec.	20 Sec.

▲ Protection required below 40 F

A **Ordinary Combustibles**
Fires in paper, wood, trash, or cloth

B **Flammable Liquids**
Fires in fuel oil, gasoline, paint, grease, solvents, and other flammable liquids

*Note: Only dry chemicals are effective on fires involving pressurized flammable gases and liquids.

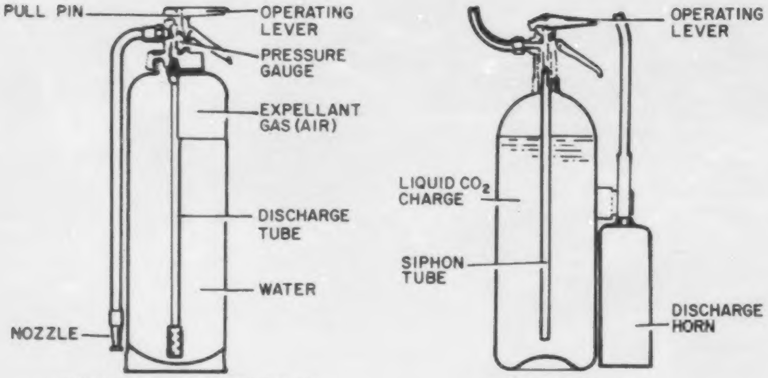
C **Electrical Equipment**
Fires in wiring, overheated fuse boxes, conductors, and other electrical sources

D **Metals**
Certain metals such as magnesium and sodium require special dry powder extinguishants

Reprinted with permission from "Selecting, Maintaining and Using Portable Fire Extinguishers" by Jeanine A. Katzel, *Plant Engineering* (March 8, 1979), pp. 94–95.

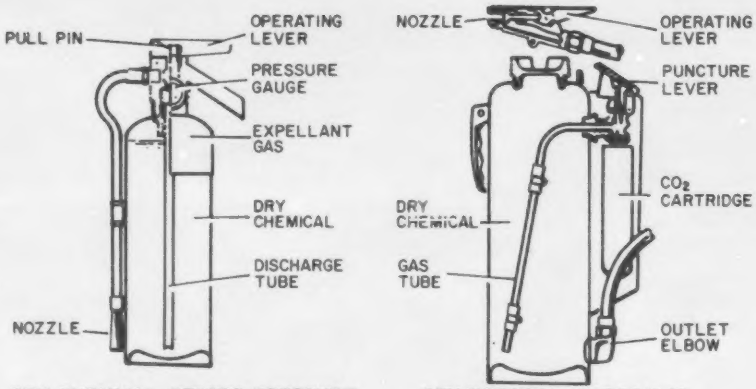
Figure 26

SOME MAJOR TYPES OF PORTABLE FIRE EXTINGUISHERS


PULL PIN
OPERATING LEVER
PRESSURE GAUGE
EXPELLANT GAS (AIR)
DISCHARGE TUBE
WATER
NOZZLE
OPERATING LEVER
LIQUID CO_2 CHARGE
SIPHON TUBE
DISCHARGE HORN

WATER-STORED PRESSURE

CARBON DIOXIDE


PULL PIN
OPERATING LEVER
PRESSURE GAUGE
EXPELLANT GAS
DRY CHEMICAL
DISCHARGE TUBE
NOZZLE
NOZZLE
OPERATING LEVER
PUNCTURE LEVER
CO_2 CARTRIDGE
DRY CHEMICAL
GAS TUBE
OUTLET ELBOW

DRY CHEMICAL-STORED PRESSURE

DRY CHEMICAL-CARTRIDGE

Among the major types of portable fire extinguishers are (A) the stored-pressure water unit, (B) the carbon dioxide unit, (C) the stored-pressure dry-chemical unit, and (D) the cartridge-operated dry-chemical unit. The internal parts of each type are shown and labelled.

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Figure 27

has more time to fight a fire. It makes little noise and creates no clouds as do gaseous or dry chemical units. Water units are available in either stored-pressure or pump-tank models (see Figure 27).

Stored-Pressure Units

Stored-pressure units have a pressure gauge at the top. The entire main tank is pressurized with dry air or nitrogen. Although antifreeze can be added to water units, only the manufacturer's recommended solution should be used. As a rule, water units must be protected from temperatures below 40°F. Therefore, they are limited to indoor heated locations.

40°F = 4°C

Pump-Tank Units

Pump-tank water units are not so common, but are effective. These units have a double-action pump that pushes water out as the operator pumps a plunger. They are not internally pressurized.

2. Aqueous Film-Forming Foam Type

A third water-base portable unit is available. It is filled with aqueous film-forming foam (AFFF). These 2-1/2-gallon stored-pressure units are unique because they are the only water-based portable units effective on Class A and B (flammable liquids) fires. Their primary ingredient is water, to which a foaming agent is added to form a premixed solution. The agent is effective on ordinary combustibles and flammable liquids, but the water base makes it a conductor of electricity. Therefore, these units are not suitable for Class C (electrical) fires.

3. Gaseous-Agent Types

There are two kinds of gaseous-agent portable extinguishers: carbon dioxide and halogenated hydrocarbon (Halon 1211 and 1301). Such extinguishers are especially effective on

1. gas and liquid flammable materials
2. electrical hazards (e.g., transformers, circuit breakers)
3. engines utilizing gasoline and other flammable fluids
4. ordinary combustibles (e.g., paper, wood, textiles)
5. hazardous solids.

Because gaseous agents leave no residue and dissipate readily, these extinguishers are used to protect costly equipment, especially in printing and duplicating areas. They are ideal for use on small electrical fires and on fires in switchgear or electrical motors.

Carbon Dioxide Units

5–20 lbs. = 2-1/2–9 kg.

Portable carbon dioxide extinguishers are available in five- to twenty-pound sizes and may be recognized by their large, cone-shaped discharge horns. CO_2 gas is self-expelling, and these units are very effective on Class B and C fires. CO_2 portable extinguishers have two major disadvantages:

1. The discharge is affected by wind and draft so that these units should be used only indoors and at close range.
2. The dilution of the oxygen in the air by the CO_2 concentration can create atmospheres that will not sustain life. Thorough ventilation is necessary after their use.

Halogenated Units

Halogenated extinguishers are among the newest portable units to be introduced. They are stored-pressure models and are most effective on Class B and C hazards. Larger units (those with more than nine pounds of agent) are rated for Class A fires as well. The major drawback of Halon portable extinguishers is cost. Although they are extremely effective and clean to use, they are perhaps the most expensive units on the market.

4. Dry Chemical Types

Dry chemical units are designed for use on Class B and C fires. The notable exception is the multipurpose dry chemical (monoammonium phosphate), which is effective on all three major classes of fires. These extinguishers are available in either stored-pressure or cartridge-operated units.

Stored-Pressure Units

In the stored-pressure unit, an expellant (usually dry nitrogen, an inert gas) and extinguishing agent are stored in one chamber; discharge is controlled by a valve. A pressure gauge at the top of the unit indicates readiness for use. Normally, pressure ranges from 100 to 195 psig.

Cartridge-Operated Units

In cartridge-operated units, the expellant gas is stored in an auxiliary cartridge adjacent to the agent-containing shell. The unit is not pressurized until the cartridge is punctured. These units have no pressure gauge and must be weighed to determine their readiness for use. It is easier to recharge a cartridge unit than a stored-pressure unit, but the stored-pressure unit is more widely used. It is best for locations where infrequent use is anticipated and where skilled personnel with professional recharge equipment are available.

Though both regular and multipurpose dry chemical units are very effective fire fighters, duration time is short and the units are among the most sensitive to operator error.

Multipurpose Dry Chemical Extinguisher

The major disadvantage to the multipurpose dry chemical extinguisher is that it clings to hot surfaces and forms a sticky film. Cleanup is difficult. Therefore, this type of unit should not be located near delicate equipment or machinery that cannot be cleaned quickly and easily. If metal surfaces do become coated with monoammonium phosphate, they should be wiped with a wet cloth and dried as soon as possible to prevent rust or corrosion. Although regular dry chemical does not adhere to hot surfaces, it does leave a residue and should be brushed away as soon as possible after use.

5. Dry Powder

Cartridge-operated portable units containing dry powder for use on Class D fires are available, but combustible metal fires present special problems. Each metal has distinctive burning characteristics that must be known before the fire can be combatted effectively. Dry powder frequently is stored in a bucket with a shovel, in the vicinity of the combustible metal hazard. Should a fire occur, the burning metal must be covered with a layer of powder at least two inches deep. The National Safety Council's Data Sheet 1-567-79, Fire Protection for Combustible Metals, is an excellent source for further information.

OBSOLETE FIRE EXTINGUISHERS

Some older fire extinguishers still in use today are considered unacceptable and unsafe (see Table 12). Obsolete models should be removed. All inverting-type extinguishers should be replaced.

Table 12

NON-ACCEPTABLE AND OBSOLETE TYPES

Non-Acceptable Types

(1) Stores Pressure Water and/or Antifreeze—Brass or fiberglass shells
(2) Dry chemical (over 2½ lb. capacity)—Brass shells
(3) Soda-acid—Brass or copper shells
(4) Foam—Brass or copper shells
(5) Cartridge-Operated Water—Brass or copper shells
(6) Cartridge-Operated Loaded Stream—Brass or copper shells

Obsolete Models

Soda-acid, foam, and cartridge-operated water types (including antifreeze and loaded stream) with stainless steel shells are recommended to be replaced because:

(1) Parts are not longer available; substitute parts should NEVER be used as they may create a serious danger.
(2) Method of operation is very difficult; does not have control valve for on-and-off operation.
(3) Listing Approval has been withdrawn by Underwriters Laboratories, Inc. (UL) and by Factory Mutual (FM).

Reprinted with permission from "Selecting, Maintaining and Using Portable Fire Extinguishers" by Jeanine A. Katzel, *Plant Engineering* (March 8, 1979), p. 95.

Inverting-Type

Because these units are no longer manufactured, suitable replacement parts are not available. These 2-1/2-gallon units, including soda-acid, foam, cartridge-operated water and cartridge-operated loaded stream types, are no longer listed by UL or approved by Factory Mutual.

Units with Brass or Copper Shells

Of these units, those with brass or copper shells are considered dangerous. The NFPA Committee on Portable Fire Extinguishers has determined that the reliability and safety of extinguishers with copper and brass shells cannot be ascertained by standard hydrostatic test methods. Stored-pressure water types with brass shells are subject to "creep." The bottom of the unit is soft soldered, and may blow out when the unit is used.

Dry Chemical Units with Brass or Fiberglass Shells

Dry chemical units with brass or fiberglass shells are also considered unsafe. The shells, which are almost identical to those of the discontinued inverting types, are susceptible to extensive corrosion and have an unacceptably high failure rate during hydrostatic testing. Some units have exploded.

Stored-Pressure Units with Fiberglass Shells

Stored-pressure units with fiberglass shells tend to rupture upon recharge. However, all of these units have been recalled by the manufacturer. Any that may remain should be taken out of service immediately. Withstanding a hydrotest is no assurance that the unit is safe; the test may weaken the fiber structure, causing the unit to explode during use.

If there is doubt about the safety or reliability of a unit, it should be removed from service and the distributor, manufacturer or NFPA should be consulted.

UNIT PLACEMENT

Becoming familiar with the kinds of units that are available is only the first step in understanding portable fire extinguishers. Placing the proper units in areas where they will be the most useful is also critical. Some of the factors to be considered are accessibility, visibility, ease of handling and appropriateness to the location.

Accessibility

Extinguishers should be located close to likely hazards but not so close that they would be damaged by fire or be inaccessible if fire occurs. For example, extinguishers should be located outside the door of a storage room rather than within the room itself, where they might become inaccessible. If the hazard is a dip tank, the fire extinguisher should not be mounted on the side of the tank. If the tank catches fire, the extinguisher is likely to be inaccessible. A better place for the unit is away from the tank on a wall or support column along normal paths of travel.

The NFPA has set the following minimum extinguisher ratings and maximum travel distance to extinguisher for Class A hazards.

SIZE AND PLACEMENT FOR CLASS A HAZARDS

	Light (Low) Hazard Occupancy	Ordinary (Moderate) Hazard Occupancy	Extra (High) Hazard Occupancy
Minimum extinguisher rating	1A	2A	3A
Maximum floor area per unit of A	3,000 sq. ft.	1,500 sq. ft.	1,000 sq. ft.
Maximum floor area per extinguisher	11,250 sq. ft.*	11,250 sq. ft.*	11,250 sq. ft.*
Maximum travel distance to extinguisher	75 ft.	75 ft.	75 ft.

*11,250 sq. ft. is considered a practical limit.

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3000 sq. ft. = 279 sq. m.
1500 sq. ft. = 139 sq. m.
1000 sq. ft. = 93 sq. m.
11,250 sq. ft. = 1045 sq. m.
75 ft. = 23 m.

The following table shows the maximum area to be protected per extinguisher. This table can be used to determine the number of extinguishers required.

Maximum Area to be Protected per Extinguisher

Class A Rating Shows on Extingiusher Nameplate	Light Hazard Occupancy	Ordinary Hazard Occupancy	Extra Hazard Occupancy
1A	3,000 sq. ft.	–	–
2A	6,000 sq. ft.	3,000 sq. ft.	2,000 sq. ft.
3A	9,000 sq. ft.	4,500 sq. ft.	3,000 sq. ft.
4A	11,250 sq. ft.	6,000 sq. ft.	4,000 sq. ft.
6A	11,250 sq. ft.	9,000 sq. ft.	6,000 sq. ft.
10A	11,250 sq. ft.	11,250 sq. ft.	10,000 sq. ft.
20A	11,250 sq. ft.	11,250 sq. ft.	11,250 sq. ft.
40A	11,250 sq. ft.	11,250 sq. ft.	11,250 sq. ft.

NOTE: 1ft.' - 0.0929 m'

2000 sq. ft. = 186 sq. m.
3000 sq. ft. = 279 sq. m.
4000 sq. ft. = 372 sq. m.
4500 sq. ft. = 418 sq. m.
6000 sq. ft. = 557 sq. m.
9000 sq. ft. = 836 sq. m.
10,000 sq. ft. = 929 sq. m.
11,250 sq. ft. = 1045 sq. m.

Reprinted with permission from NFPA 10, Portable Fire Extinguishers 1978, *National Fire Codes.*

The NFPA has set the following minimum extinguisher ratings and maximum travel distances to extinguisher for Class B hazards.

Type of Hazard	Basic Minimum Extinguisher Rating	Maximum Travel Distance to Extinguishers (Ft.)	(m)
Light (low)	5B	30	9.15
	10B	50	15.25
Ordinary (moderate)	10B	30	9.15
	20B	50	15.25
Extra (high)	40B	30	9.15
	80B	50	15.25

NOTE: The specified ratings do not imply that fires of the magnitudes indicated by these ratings will occur, but rather to give the operators more time and agent to handle difficult spill fires that may occur.

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These NFPA standards form the basis for most mandatory rules adopted by federal, state and local agencies. Local fire authorities will help apply these requirements to the individual industrial/vocational education shop. They also can determine which shop areas fall under light, ordinary and extra hazard occupancy.

Visibility

In general, both for accessibility and visibility, extinguishers should be placed at exits, where they can be used to fight fires while still allowing the firefighter to escape. In this location students and instructors will see the extinguisher each time they enter or leave and will know where to find it if it is needed. Care must be taken, however, not to obstruct the exit in any way.

A fire extinguisher must not be blocked or hidden by stock, equipment or machines. It must be located where it will not be damaged by equipment, corroded by chemical processes or exposed to the elements. Its location should be made conspicuous. For example, if it is hung on a column or post, a red band can be painted around the post. The extinguisher must be kept clean. It should not be painted in a way that will camouflage it or obscure labels or markings.

Ease of Handling
40 lbs. = 18 kg.
5' = 1-1/2 m.
3-1/2' = 1 m.

For ease of lifting, extinguishers weighing less than forty pounds should be placed so that their tops are not more than five feet above the floor. Extinguishers weighing more than forty pounds should not be more than 3-1/2 feet above the floor.

Appropriateness to the Situation

To determine where portable extinguishers should be placed and what ratings are needed, it is necessary to look at what is in the shop and what is likely to burn. Areas with protection from automatic systems or hose stations will not need as many portable extinguishers as a completely unprotected area. However, if conditions permit, it is far more desirable to put out a small fire with a portable fire extinguisher than to rely on a fixed system that, if triggered, could create a cleanup problem. Portable fire extinguishers can prevent a small fire from spreading and can extinguish a fire rapidly in its early stages.

Hazards should be itemized. Where is a fire most likely to start? What kind of fire is likely? How does the expense of the unit compare with the cost of cleanup? While it may be cheaper to install one dry chemical multipurpose unit (A, B, and C capabilities) instead of both a large water unit (A capability) and a small Halon 1211 extinguisher (B and C capabilities), the less expensive unit may create a much greater problem with cleanup than the two separate units.

When units are placed, adjacent hazards should be considered. If a flammable liquid fire could ignite surrounding combustible paper and wood, the fire extinguisher selected should have both A and B capabilities. If nearby electrical equipment may catch fire, then the agent inside the extinguisher should be nonconductive.

Ambient temperatures may be important. If the storage area is unheated or only minimally heated, water units may freeze. A multipurpose dry chemical unit that will operate at temperatures from 40°F to 120°F is a better choice.

40–120°F = 4–49°C

Analyzing hazards in this fashion often means that the school shop will exceed NFPA recommendations, which offer minimum standards. The industrial/vocational education supervisor should not hesitate to seek assistance from the local fire department or from a fire equipment distributor.

TRAINING AND MAINTENANCE REQUIREMENTS

Instructors and student shop foremen should be trained in the use of portable fire extinguishers. Training in proper use includes:

1. using a sweeping motion that extends at least six inches on each side of the near edge of the flames
2. maintaining a proper distance from the fire to avoid splashing fuel or burning material

6" = 15 cm.

3. holding portable units upright
4. attacking flames at the fuel source
5. keeping the agent flowing so that the fire cannot reignite.

Instructors and student shop foremen should learn to react quickly. Besides knowing how to operate extinguishers and how to apply agents effectively, they should be familiar enough with the equipment to know when a fire is beyond the capabilities of portable extinguishers.

Manufacturers of portable fire extinguishers work hard to make a product of high quality; units and their components are tested before assembly. Most portable units are approved by Factory Mutual (FM) for the classes of fire for which they are suitable, or they are listed by Underwriters Laboratories (UL), rated for class of fire and extinguishing potential. Many units bear the seals of both testing agencies, whose quality control representatives inspect manufacturers periodically, exercising continual, careful control over the products they have approved or listed.

But any unit that is improperly maintained can pose a hazard. Carbon dioxide units may explode if subjected to severe neglect and corrosion or if exposed to extremely high temperatures when the relief valve fails to operate.

Mixing different types of multipurpose dry chemicals may produce a violent reaction. An extinguisher that has been even partially discharged must be recharged with the same kind of chemical.

Monthly Inspections

Extinguishers should be inspected monthly to be certain of the following:

1. They are in their designated places.
2. Access and visibility are unobstructed.
3. The operating instructions on the extinguisher nameplate and legible and facing outward.
4. Any seals or tamper indicators that are broken or missing must be replaced.

5. They have no obvious physical damage, corrosion, leakage or clogged nozzles.
6. Pressure gauge readings are in the operable range. Water types without gauges should be hefted to determine fullness.

Annual Maintenance

Extinguishers should be maintained at least yearly or according to nameplate instructions. A tag must be attached to show the maintenance or recharge date and the signature or initials of the person performing the service.

Maintenance procedures should include a thorough examination of the three basic elements of an extinguisher:

1. mechanical parts
2. extinguishing agent
3. expelling means.

Specific maintenance requirements for various types of extinguishers are included in NFPA 10, Portable Fire Extinguishers.

Hydrostatic Testing

Every six years stored pressure extinguishers requiring a twelve-year hydrostatic test should be emptied and serviced. The extinguisher sales representative usually will perform this service at appropriate intervals.

EMERGENCY PROCEDURES

Except for obviously incipient fires which can be extinguished easily in their first phase, the local fire department should be notified immediately in case of fire. A list of telephone numbers for local fire departments should be posted in a prominent place near the shop telephone. Students should be aware of this list.

Floor plans for designated areas should be posted, showing the locations of fire alarm activators, fire extinguishers and exits.

While the fire department is being notified and while the fire is being combatted, students should shut off all power to machines and fans and then begin an orderly evacuation from the facility. A plan for orderly evacuation should include the following:

- an evacuation signal

- a well planned evacuation route for all areas of the shop
- designation of an assembly area for students well away from the school
- an accounting procedure for all persons after assembly, keeping in mind those absent from the shop that day
- if possible, a search of the building to assure complete evacuation.

CONCLUSION

In this unit we have discussed common causes of fires and precautions necessary to prevent their occurrence. We have seen how certain structural devices can protect against fire and limit its spread. We have outlined the actual fire control apparatus, including

- detection and alarm systems
- automatic sprinkler systems
- special systems to control specific hazards
- portable fire extinguishers, the first line of defense.

We have reviewed the proper emergency procedure to follow when a fire occurs. Now we turn our attention to some other hazards found in the industrial/vocational education shop.

NOTES

1. The chemistry of uninhibited chain reaction is explained in *Accident Prevention Manual for Industrial Operations*, 7th ed. (Chicago: National Safety Council, 1974), pp. 1341–1342.
2. Adapted from *Supervisors Safety Manual*, 5th ed. (Chicago: National Safety Council, 1978), p. 371.
3. The sections on static electricity and on bonding and grounding are adapted from the *Accident Prevention Manual*, pp. 1291–1295.
4. This section is adapted from *Fire and Explosion Prevention and Protection*, U.S. Department of Labor, Bulletin 296 (1967), pp. 28–32.

5. This section is adapted from the *Accident Prevention Manual*, pp. 582–583, and *Fire Explosion Prevention and Protection*, pp. 41–42.

6. The following discussion of portable fire extinguishers owes much to the definitive article by Jeanine A. Katzel, "Selecting, Maintaining and Using Portable Fire Extinguishers," *Plant Engineering* (March 8, 1979), pp. 92–101. A shorter version of the article appeared in *National Safety News* (June 1979), pp. 52–58.

7. *Accident Prevention Manual*, p. 1343.

QUESTIONS AND ANSWERS

1. To produce combustion, what elements must be present?

a. fuel

b. oxygen

c. heat

d. uninhibited chain reaction.

2. Define *flash point* and tell the difference between flammable and combustible liquids. 100°F = 38°C

Flash point is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitible mixture with air near the surface of the liquid. Flammable liquids are those with flash points below 100°F; combustible liquids are those with flash points at or above 100°F.

3. Fires in the industrial/vocational education shop may be traced back to many causes. What kind of fire is most frequent, and what are some specific causes?

The most frequent fires are electrical fires, from such causes as electrical arcing, short circuits, overheated electrical equipment and substandard wiring.

4. Name the four classes of fires and what items belong to each class.

a. Class A—fires in ordinary combustible materials (e.g., wood, cellulose, paper, cloth, excelsior, rubber)

b. Class B—fires in flammable liquids, gases and greases

c. Class C—fires which involve electrical equipment

d. Class D—fires occurring in combustible metals

5. What are the two types of automatic sprinkler systems most likely to be found in the industrial/vocational education shop?

Wet-pipe and dry-pipe

6. List five requirements for effective portable fire extinguishers.

Any five from among the following. They must be:

a. a reliable type

b. the right type for each class of fire that may occur in the area

c. in sufficient quantity to protect against exposure in the area

d. located where they are readily accessible for immediate use

e. maintained in perfect operating condition, inspected frequently, checked against tampering and recharged as required

f. operable by the persons who are in the area, who can find them and who are trained to use them effectively and promptly.

7. In case of fire, what is the first emergency step to be taken?

Notify the fire department.

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APPENDIX A

EXAMPLES OF TYPICAL INCOMPATIBLE CHEMICALS

Table 13
EXAMPLES OF INCOMPATIBLE CHEMICALS

Chemical	Keep Out of Contact with:
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkaline metals, such as powdered aluminum or magnesium, sodium, potassium	Water, carbon tetrachloride or other clorinated hydrocarbon, carbon dioxide and the halogens
Ammonia, anhydrous	Mercury (in manometers, for instance), chlorine, calcium hypochlorite, iodine, bromine, hydrofluric acid (anhydrous)
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Bromine	Same as for chlorine
Carbon, activated	Calcium hypochlorite and all oxidizing agents
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chlorine	Ammoniz, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Chromic acid	Acetic acid, naphthalene, camphor, glycerine, turpentine, alcohol and flammable liquids in general
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids—organic and inorganic
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide and the halogens
Fluorine	Isolate from everything
Hydrocarbons (butane, propane, benzene, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide

EXAMPLES OF INCOMPATIBLE CHEMICALS (Concluded)

Chemical	Keep Out of Contact with:
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluric acid, anhydrous	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, combustible materials
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitric acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Oxalic acid	Silver, mercury
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate (see also "Chlorates")	Sulfuric and other acids
Potassium permanganate	Glycerine, ethylene glycol, benzaldehyde, sulphuric acid
Silver	Acetylene, oxalic acid, tartaric acid, fulminic acid, ammonium compounds
Sodium	Carbon tetrachloride, carbond dioxide, water
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydridge, bezaldehyde, carbon disulfide, glycerine ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or such compounds with similar light metals, such as sodium lithium, etc.)

Reprinted with permission from *Accident Prevention Manual for Industrial Operations,* 7th ed. (Chicago: National Safety Council, 1974), p. 1462.

APPENDIX B

CHARACTERISTICS OF PORTABLE FIRE EXTINGUISHERS

Table 14

CHARACTERISTICS OF PORTABLE FIRE EXTINGUISHERS

Extinguishing Agent	Method of Operation	Capacity	Horizontal Range of Stream	Approximate Time of Discharge	Protection Required Below 40°F (4°C)	UL or ULC Classifications*
Water	Stored Pressure	2½ gal.	30-40 ft.	1 min.	Yes	2-A
Water	Pump	1½ gal.	30-40 ft.	45 sec.	Yes	1-A
	Pump	2½ gal.	30-40 ft.	1 min.	Yes	2-A
	Pump	4 gal.	30-40 ft.	2 min.	Yes	3-A
	Pump	5 gal.	30-40 ft.	2-3 min.	Yes	4-A
Water (Antifreeze Calcium Chloride)	Cartridge & Stored Pressure	1¼, 1½ gal.	30-40 ft.	30 sec.	No	1-A
	Cartridge & Stored Pressure	2½ gal.	30-40 ft.	1 min.	No	2-A
	Cartridge & Stored Pressure	23 gal. (wheeled)	50 ft.	3 min.	No	20-A
Water (Wetting Agent)	Cartridge & Stored Pressure	25 gal. (wheeled)	35 ft.	1½ min.	Yes	10-A
	Cartridge & Stored Pressure	45 gal. (wheeled)	35 ft.	2 min.	Yes	30-A
Water (Soda Acid)	Chemically generated expellent	1¼, 1½ gal.	30-40 ft.	30 sec.	Yes	1-A
	Chemically generated expellent	2½ gal.	30-40 ft.	1 min.	Yes	2-A
	Chemically generated expellent	17 gal. (wheeled)	50 ft.	3 min.	Yes	10-A
	Chemically generated expellent	33 gal. (wheeled)	50 ft.	3 min.	Yes	20-A
Loaded Stream	Stored Pressure	2½ gal.	30-40 ft.	1 min.	No	2 to 3-A and 1-B
	Cartridge & Stored Pressure	33 gal. (wheeled)	50 ft.	3 min.	No	20-A
Foam	Pressurized	21 oz.	4-6 ft.	24 sec.	Yes	1-B
Foam	Chemically generated expellent	1¼, 1½ gal.	30-40 ft.	40 sec.	Yes	1-A, 2-B
	Chemically generated expellent	2½ gal.	30-40 ft.	1½ min.	Yes	2-A:4-B to 2-A:6-B
	Chemically generated expellent	5 gal.	30-40 ft.	2 min.	Yes	4-A:6-B
	Chemically generated expellent	17 gal. (wheeled)	50 ft.	3 min.	Yes	10-A:10-B to 10-A:12-B
	Chemically generated expellent	33 gal. (wheeled)	50 ft.	3 min.	Yes	20-A:20-B to 20-A:40-B
AFFF	Stored Pressure	2½ gal.	20-25 ft.	50 sec.	Yes	3-A:20-B
Carbon Dioxide **	Self Expellent	2½ to 5 lb.	3-8 ft.	8 to 30 sec.	No	1 to 5-B:C
		10 to 15 lb.	3-8 ft.	8 to 30 sec.	No	2 to 10-B:C
		20 lb.	3-8 ft.	10 to 30 sec.	No	10-B:C
		50 to 100 lb. (wheeled)	3-10 ft.	10 to 30 sec.	No	10 to 20-B:C
Dry Chemical (Sodium Bicarbonate)	Stored Pressure	1 lb.	5-8 ft.	8 to 10 sec.	No	1 to 2-B:C
	Stored Pressure	1½ to 2½ lb.	5-8 ft.	8 to 12 sec.	No	2 to 5-B:C
	Cartridge and Stored Pressure	2¾ to 5½ lb.	5-20 ft.	8 to 20 sec.	No	5 to 10-B:C
	Cartridge and Stored Pressure	7½ to 30 lb.	5-20 ft.	10 to 25 sec.	No	10 to 120-B:C
	Nitrogen cylinder or Stored Pressure	75 to 350 lb. (wheeled)	15 to 45 ft.	20 to 105 sec.	No	40 to 240-B:C
Dry Chemical (Potassium Bicarbonate)	Stored Pressure	1 to 2 lb.	5-8 ft.	8 to 10 sec.	No	1 to 5-B:C
	Stored Pressure	2¼ to 5 lb.	5-12 ft.	8 to 10 sec.	No	5 to 20-B:C
	Cartridge or Stored Pressure	5½ to 10 lbs.	5-20 ft.	8 to 20 sec.	No	10 to 60-B:C
	Cartridge or Stored Pressure	16 to 30 lbs.	10-20 ft.	8 to 25 sec.	No	40 to 120-B:C
	Nitrogen cylinder or Stored Pressure	125 to 300 lbs. (wheeled)	15-45 ft.	30 to 60 sec.	No	80 to 480-B:C

Characteristics of Extinguishers (continued)

Extinguishing Agent	Method of Operation	Capacity	Horizontal Range of Stream	Approximate Time of Discharge	Protection Required Below 40°F (4°C)	UL or ULC Classifications*
Dry Chemical (Potassium Chloride)	Stored Pressure	2 to 2½ lbs.	5-8 ft.	8 to 10 sec.	No	5 to 10-B:C
	Cartridge or Stored Pressure	5 to 10 lbs.	5-20 ft.	8 to 25 sec.	No	20 to 40-B:C
	Cartridge or Stored Pressure	19½ to 30 lbs.	15-45 ft.	8 to 25 sec.	No	60 to 80-B:C
	Nitrogen cylinder or Stored Pressure	50 to 160 lbs. (wheeled)	15-45 ft.	30 to 60 sec.	No	120 to 160-B:C
Dry Chemical (Ammonium Phosphate)	Stored Pressure †	1 to 5 lbs.	5-12 ft.	8 to 10 sec.	No	1 to 2-A and 2 to 10-B:C
Dry Chemical (Ammonium Phosphate)	Stored Pressure or Cartridge	2½ to 8½ lbs.	5-12 ft.	8 to 12 sec.	No	1 to 3-A and 10 to 40-B:C
	Stored Pressure or Cartridge	9 to 17 lbs.	5-20 ft.	10 to 25 sec.	No	2 to 10-A and 10 to 60-B:C
	Stored Pressure or Cartridge	17 to 30 lbs.	5-20 ft.	10 to 25 sec.		3 to 20-A and 30 to 80-B:C
	Nitrogen Cylinder or Stored Pressure	50 to 315 lbs. (wheeled)	15-45 ft.	30 to 60 sec.		20 to 40-A and 60 to 320-B:C
Dry Chemical (Foan Compatible)	Cartridge and Stored Pressure	4¾ to 9 lbs.	5-20 ft.	8 to 10 sec.	No	10 to 20-B:C
	Cartridge and Stored Pressure	9 to 27 lbs.	5-20 ft.	10 to 25 sec.	No	20 to 30-B:C
	Cartridge and Stored Pressure	18 to 30 lbs.	5-20 ft.	10 to 25 sec.	No	40 to 60-B:C
	Nitrogen cylinder and Stored Pressure	150 to 350 lbs. (wheeled)	15-45 ft.	20 to 150 sec.	No	80 to 240-B:C
Dry Chemical (Foam Compatible) (Potassium Chloride)	Cartridge and Stored Pressure	2½ to 5 lbs.	5-12 ft.	8 to 10 sec.	No	10 to 20-B:C
	Cartridge and Stored Pressure	9½ to 20 lbs.	5-20 ft.	8 to 25 sec.	No	40 to 60-B:C
	Cartridge and Stored Pressure	19½ to 30 lbs.	5-20 ft.	10 to 25 sec.	No	60 to 80-B:C
	Nitrogen cylinder and Stored Pressure	50 lbs. (wheeled)	15-45 ft.	30 sec.	No	120-B:C
Dry Chemical (Foam Compatible) (Potassium Bicarbonate Urea based)	Stored Pressure	5 to 11 lbs.	11-22 ft.	13 to 18 sec.	No	40 to 80-B:C
	Stored Pressure	9 to 23 lbs.	15-30 ft.	17 to 33 sec.	No	60 to 160-B:C
		175 lbs. (wheeled)	70 ft.	62 sec.	No	480-B:C
Bromotrifluoromethane	Self Expellent	2½ lbs.	4-6 ft.	8 to 10 sec.	No	2-B:C
	Stored Pressure	4½ lbs.	6-10 ft.	8 to 10 sec.	No	5-B:C
Bromochlorodifluoromethane	Stored Pressure	2 to 4 lbs.	8-12 ft.	8 to 12 sec.	No	2 to 5-B:C
		5½ to 9 lbs.	9-15 ft.	8 to 15 sec.	No	1-A and 10-B:C
		16 to 22 lbs.	14-16 ft.	10 to 18 sec.	No	1 to 2-A and 20 to 80-B:C

Note: 1 oz. = 29.6 mi; 1 lb. = 0.454 kg; 1 ft. = 0.305 m; 1 gal. = 3.785

*UL and ULC ratings checked as of December 27, 1974. Readers concerned with subsequent ratings should review the pertinent "Lists" and "Supplements" Issued by these Laboratories: (Write Underwriters Laboratories Inc., 207 East Ohio St., Chicago, Illinois 60611, or Underwriters' Laboratories of Canada, 7 Crouse Road, Scarborough, Ont., Canada MIR 349).

**Carbon-dioxide extinguishers with metallic horns do not carry a "C" classification.

†Some small extinguishers containing ammonium phosphate dry chemical do not carry on "A" classification.

Vaporizing liquid extingiushers (Carbon tetrachloride or chlorobromomethane base) are not recognized in this standard.

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UNIT 13

HEALTH HAZARDS

METHODS Lecture and Demonstration LENGTH: 2 Hours

PURPOSE To show what health hazards exist in the industrial/vocational education shop and how these hazards can be evaluated and controlled.

OBJECTIVES To introduce the participant to:

1. Characteristics of health hazards
2. Classification of health hazards
3. The dangers presented by such physical agents as radiation, vibration and noise
4. The adequate labeling, careful use and proper disposal of chemical agents
5. The modes of entry for hazardous substances
6. Methods of evaluating and controlling health hazards.

SPECIAL TERMS

1. Visible Light
2. Infrared Radiation
3. Ultraviolet Radiation
4. Sound
5. Pitch
6. Intensity
7. Decibel
8. Temporary Threshold Shift
9. Permanent Threshold Shift
10. Primary Irritants
11. Sensitizers
12. Threshold Limit Value
13. Time-Weighted Average
14. Permissible Exposure Level

7 **INSTRUCTOR MATERIALS**

Lesson Plan
35 mm Slides and Projector
Chalk Board/Chalk

TRAINEE MATERIALS Participant Outlines and Supplementary Materials

UNIT 13

HEALTH HAZARDS

INTRODUCTION

For years industrial/vocational education instructors have been concerned with locating and eliminating or at least controlling safety and health hazards in their school shops. But, because health hazards and their destructive impact often are not fully understood, many health hazards exist within industrial/vocational shops without arousing the concern they deserve. Thus students are often exposed to excessive machinery noise, chemical agents which may cause dermatitis, and such airborne contaminants as fumes from welding operations, dusts from grinding and vapors from solvents. Such exposure can have both short- and long-term effects on the health of both students and instructors.

During our discussion of accident causes in Unit 1, environmental factors (biological, physical and chemical) were mentioned as causes of accidents in the industrial/vocational school. In this unit, that discussion will be expanded to provide a more thorough understanding of the health hazards arising from environmental factors and ways that these hazards can be eliminated or controlled.

CHARACTERISTICS OF HEALTH HAZARDS FOUND IN THE SCHOOL SHOP

Health hazards encountered in the industrial/vocational education shop have the following characteristics:

1. They cover a whole range of disorders involving many parts of the body (e.g., lungs, liver, blood, kidney, skin, eyes, ears, brain and nervous system).
2. They frequently escape detection.
3. They do not come with a label; thus, they easily can be misdiagnosed by a physician.
4. They come slowly as a rule, over months and years, and every person is not affected by them.

Instructor Note:
Instructor solicits from participants the environmental factors in their respective shops which they think are potential health hazards. Replies are recorded on the chalk board.

5. New potential hazards continually are introduced through the use of new substances, new uses for old materials, new combinations of chemicals and process changes.

CLASSIFICATION OF HEALTH HAZARDS

Instructor Note:
Instructor groups into the three categories the factors mentioned by the participants.

Health hazards which may adversely affect both instructors and students may be classified according to the following three categories:

Category A — Biological Agents
Category B — Physical Agents
Category C — Chemical Agents

BIOLOGICAL AGENTS

Biological agents—certain bacteria, fungi, parasites and microorganisms—are known to cause illness, extreme discomfort and, in some circumstances, even death. It is unlikely, however, that operations involving these agents will be part of the industrial/vocational education curriculum. Biological agents are of particular concern to persons handling hides and skins, to butchers and others working with animal products, and to employees of sewage treatment facilities and waste areas.

PHYSICAL AGENTS

Illumination

Physical agents are far more likely than biological agents to present health hazards in the industrial/vocational education environment. In the unit on illumination we have seen how inadequate lighting and glare can contribute to eyestrain and fatigue and can cause accidents.

Temperature
Humidity

Temperature extremes and humidity are other factors which affect safety and health. However, it is unlikely that shops deviate significantly from comfortable temperature ranges.

Radiation
Vibration
Noise

We will now look at other physical agents which present health hazards in the shop environment: radiation, vibration and noise.

RADIATION

The electromagnetic (non-ionizing) radiation that may be encountered in the industrial/vocational education shop can affect the body adversely. Infrared, visible and ultraviolet radiation are manifestations of the same kind of electromagnetic radiation, differing from each other only in frequency, wavelength or energy level. It is useful to discuss them as separate groups because of the physical effects which they produce.

Visible light is radiation that can be seen and includes the color spectrum, from red, orange, yellow and green to blue, indigo and violet. The region beyond the red is infrared; the region beyond the violet is ultraviolet. Though radiation in these regions is invisible, it is a form of energy particularly dangerous to the human eye. The eye is an optical instrument equipped to receive radiations which are not limited to the visible portion of the electromagnetic spectrum. Because of its receiving ability and the delicate balance of its functional parts, it is easily injured.

Infrared Radiation (IR)

Infrared radiation does not penetrate below the superficial layer of the skin. Its only effect is to heat the skin and the tissues immediately below it. Except for thermal burns and damage to the eye, it presents a negligible health hazard.

Infrared radiation is encountered in various shop operations:

1. drying and baking of paints, varnishes, enamels, adhesives, printers' ink and other protective coatings
2. heating of metal parts, especially through use of the electric arc and other flame-cutting devices
3. dehydrating of textiles, paper and other materials.

The major danger of IR, as with other forms of electromagnetic radiation, is to the eye. Low doses of IR over the years may not be felt but may cause serious permanent damage to the cornea, iris, retina and lens of the eye. It can produce "heat cataract," an opacity of the rear surface of the lens which is particularly frequent among glassblowers and persons who work near industrial ovens and furnaces.

Goggles protect the eyes and regular clothing protects the skin against the dangers of IR. Ovens and other sources of IR can be shielded with shiny materials such as polished aluminum, which will reflect the heat back to its source.

Intense Visible Radiation

Intense visible radiation is emitted from the sun, artificial light sources, arc welding processes and highly incandescent bodies. The physiological responses to intense visible light—adaptation, pupillary reflex, partial or full lid closure and shading of the eyes—are protective mechanisms to prevent excessive brightness from being focussed on the retina.

In arc welding, the welder's eye protection equipment prevents exposure to intense visible light. Because others in the area can sustain retinal damage because they accidentally or carelessly view the electric arc, welding areas should be shielded and/or isolated.

Ultraviolet Radiation (UV)

Ultraviolet radiation is the portion of sunlight which causes sunburn, and the most common exposure to UV is from direct sunshine. Symptoms of overexposure include reddening of the skin, blistering and pain. UV radiation intensifies the effects of some chemicals. Long-term exposure to UV, especially when combined with such photo-sensitizing agents as the coal tars and cresols used in roofing, increases a person's chances of developing skin cancer. Certain protective creams contain compounds which minimize the effect of UV rays.

Many welding processes, especially the use of the electric arc, produce UV which can damage the eyes. Many arc welders are aware of the sensation of sand in the eyes which is known as "arc-eye" or keratitis. This painful condition occurs six to eight hours after exposure and is the result of excessive exposure to UV. Long-term exposure to UV can lead to loss of vision. Welders must wear eye protection equipment with the appropriate shade lens.

UV reacts with chlorinated hydrocarbons—perchloroethylene, trichloroethylene and other chemicals commonly used as degreasers—to form phosgene, a highly toxic nerve gas. To prevent such a reaction, welding operations should be shielded or isolated.

Conventional light sources produce random and disordered light wave mixtures of various frequencies. In contrast, lasers emit beams of coherent light of a single color or wavelength and frequency. Laser is an acronym for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation.

Lasers

Lasers are relatively new, and their use in industry is becoming more frequent. They are useful for projecting a reference line for construction work and for highly precise distance measuring in surveying. In the industrial/vocational education shop, an all-purpose laser machine may be used for welding, cutting and drilling and for micromachining fine parts.

Because the laser has a large energy density in a narrow beam, it can inflict serious injury, especially to the eye. Not only is it important to protect those persons who might view the direct beam but also those who might see a reflection. Hazard controls include barriers, shields and protective equipment.

Other Radiation Forms

The longer wavelengths—including power frequencies and broadcast and short wave radio—can produce general heating of the body.

Radiofrequency Waves

Radiofrequency waves can be used as heating sources in various industrial/vocational education operations. Such heating equipment is used in metalworking for hardening gear teeth, cutting tools and bearing surfaces and for annealing, soldering and brazing. In woodworking, radiofrequency heating equipment is used for bonding plywood, laminating and general gluing. Other uses include molding plastics, curing and vulcanizing rubber and thermosealing. The waves themselves are unlikely to emit sufficient exposure intensities to cause a radiation health hazard. The hazards of radiofrequency heating are electrical shock and burns, hazards which will be discussed in a subsequent unit on electricity.

Microwaves

Microwaves are far more dangerous than radiofrequency waves. Where microwaves are used for radar or communications, their hazards must be realized and necessary precautions taken.

Radar

Radar operates on the principle of microwave radiation echoing in a wavelength range from several meters to several millimeters. It can damage many parts of the body: eyes, testes, gall bladder, gastrointestinal tract and certain other vital organs. Persons who work in or around high-power radar antennas or radar test equipment must minimize their exposure.

MECHANICAL VIBRATION

Another physical health hazard encountered in the industrial/vocational education shop is the vibration produced by such pneumatic tools as air hammers, compressed-air chisels, jackhammers, riveting guns, pounding-up machines and stonecutting hammers. The bodily response to vibration, which is often accompanied by noise, is a feeling of unease, fatigue, irritability and discomfort.

A condition known as "dead fingers" or "white fingers" is produced by vibration of even fairly light tools while the fingers are held in a strained position. When the fingers are chilled at the same time that they are cramped, the condition is aggravated. Preventive measures include gloves, use of handles of comfortable size for the fingers and directing the exhaust air from air-driven tools away from the hands so that they will not become unduly chilled. Because the condition is aggravated by gripping the vibrating tool too tightly, students should be taught the proper way to hold pneumatic tools.

NOISE[1]

Everyone at some time is exposed to noises that have the potential to damage the hearing. Ordinary shop noises—for example, those produced by compressors and circular saws—can cause hearing damage if there is sufficient exposure time. Noises at high levels of intensity do not require lengthy exposure time to cause hearing damage.

To understand how hearing can be damaged by noise, we first must understand something about both the characteristics of sound and the process of hearing.

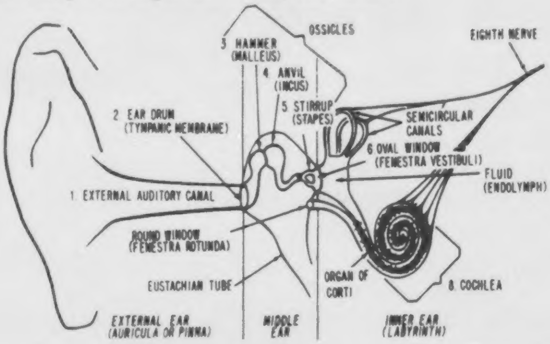
Nature of Sound

Sound travels through the air in the form of a series of moving pressure disturbances or waves. These pressure waves, which are caused by minute back-and-forth movements of the air molecules, are formed by the vibration or motion of the sound source. A rough analogy to the motion of sound waves in the air is the motion of water waves on the surface of a pool of water when a rock is thrown into it.

As the energy is transmitted, the pressure variations reach the eardrum, and the vibrations are translated by the hearing system into a sensation called sound. A sound is not a sound until the brain identifies it as such.

Process of Hearing

Figure 28 can be used to trace the path of a sound from its source inside the body through the air to the brain:


OSSICLES
3 HAMMER (MALLEUS)
4 ANVIL (INCUS)
5 STIRRUP (STAPES)
EIGHTH NERVE
2 EAR DRUM (TYMPANIC MEMBRANE)
SEMICIRCULAR CANALS
6 OVAL WINDOW (FENESTRA VESTIBULI)
FLUID (ENDOLYMPH)
1. EXTERNAL AUDITORY CANAL
ROUND WINDOW (FENESTRA ROTUNDA)
EUSTACHIAN TUBE
ORGAN OF CORTI
8 COCHLEA
EXTERNAL EAR (AURICULA OR PINNA)
MIDDLE EAR
INNER EAR (LABYRINTH)

-How the ear hears. Wave motions in the air set up sympathetic vibrations which are transmitted by the eardrum and the three bones in the middle ear to the fluid-filled chamber of the inner ear. In the process, the relatively large but feeble air-induced vibrations of the eardrum are converted to much smaller but more powerful mechanical vibrations by the three ossicles, and finally into even stronger fluid vibrations. The wave motion in the fluid is sensed by the nerves in the cochlea, which transmit neural messages to the brain.

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Figure 28

1. Sound waves enter the external auditory canal (1) and are directed to the eardrum or tympanic membrane (2), causing it to vibrate.

2. The eardrum passes the vibrations to the three small bones located within the middle ear: the hammer or malleus, (3), the anvil or incus (4), and the stirrup or stapes (5).

3. These three small bones pass the vibration along to the oval window (6), which is connected to the inner ear. The major components of the inner ear are the vestibular system or semicircular canals (7) and the cochlea (8), a small snail-shaped bony structure filled with fluid and lined with tiny hair cells. The oval window passes the vibrations along to the fluid in the cochlea, which in turn stimulates the hair cells in the cochlea.

4. The hair cells change the vibrations to electrical signals which are carried to the brain and identified by the brain as sound.

Characteristics of Sound

Sound may be understood in terms of its two basic characteristics, pitch and intensity.

1. Pitch

Sound travels through the air in the form of pressure disturbances or waves. The frequency with which the waves strike our ears determines the pitch of the sound. The higher the frequency of the waves, the higher the pitch of the sound.

Within a sound wave, each pressure disturbance or back-and-forth movement of the air molecules is referred to as a cycle of the wave. The frequency of sound waves can therefore be measured in terms of the number of cycles per second (CPS) that are generated by a sound source. The unit commonly used to describe frequency is the hertz (Hz). One hertz is equivalent to one cycle per second.

A sound source vibrating rapidly—for example, 10,000 times per second—will produce a sound that strikes our ears at a frequency of 10,000 cycles per second (10,000 Hz). This is a sound of relatively high pitch, very near the upper limit of human hearing. A sound source vibrating slowly—for example, 200 times per second—will produce a sound of 200 cycles per second (200 Hz), which is a sound of relatively low pitch.

2. Intensity

Intensity, the second characteristic of sound, is what we commonly understand by loudness. While the pitch of a sound is determined by the frequency of the waves, the intensity of a sound is determined by the size of the air pressure disturbance. A larger pressure disturbance results in a sound of higher intensity; a smaller pressure disturbance results in a sound of lower intensity.

Decibels

Air pressure disturbance of sound waves is measured in units called decibels (dB). The higher the number of decibels, the greater the pressure disturbance and the more intense the sound. The sound produced by a gasoline-powered lawnmower, at about 90 decibels, would be considered of high intensity; the sound of leaves rustling, at about 20 decibels, would be considered very low intensity.

Distinguishing Between Sound and Noise

The difference between sound and noise is subjective. Noise might be defined simply as unwanted sound. Whatever it is called, noise or sound can be a definite health hazard, interfering with job performance and safety and causing psychological distress and loss of hearing.

Threshold of Hearing

Everyone has what is known as a threshold of hearing, the sound level below which no sounds are heard. For most young people with normal hearing sensitivity, this threshold of hearing occurs near zero decibels. The decibel scale was developed so that its zero point would coincide approximately with the threshold of hearing.

Noise at high levels of intensity can raise this threshold so that we are unable to hear sounds at lower decibel levels, sounds that normally we can hear. Intense noise can raise the threshold on a temporary or permanent basis.

Temporary Threshold Shift (TTS)

A Temporary Threshold Shift (TTS) is a condition in which we temporarily lose the ability to hear sounds at lower decibel levels. The TTS occurs during our exposure to potentially damaging noise. The TTS noticed after the noise has subsided or after we have removed ourselves from the noise. It is at this point that we may become aware that certain lower decibel sounds that are normally easy to hear are now more difficult to hear or perhaps cannot be heard at all.

Nature of Damage to the Ear

This threshold shift is the result of damage to the tiny hair cells within the cochlea. These are the cells that ultimately transmit sound to the brain in the form of electrical impulses. When these cells are damaged, the brain does not receive sound signals. The sounds simply are not heard.

Intense noise damages the hair cells by overstimulating or overloading them, thus weakening their ability to transmit signals to the brain. Given an opportunity to recover (being removed from the source of the damaging noise), the hair cells generally will do so. Following a recovery period, which usually is a few hours, the threshold of hearing will return again to its normal level.

Permanent Threshold Shift (PTS)

But this return to a normal threshold level does not always occur. When it does not, we experience a Permanent Threshold Shift (PTS). A PTS is a condition in which we permanently lose the ability to hear sounds at lower decibel levels. One of the most harmful effects of such a hearing loss is that we lose some of our ability to understand speech. A PTS can result from a single damaging exposure to very high intensity noise but most often results from exposure to moderately intense noise over an extended period of time.

A permanent hearing loss can occur over time without our even being aware of it. If exposed to sufficiently high levels of noise over time, we find our ability to hear diminished little by little —not enough at any one time for the loss of hearing to be noticeable.

Unfortunately, hearing loss is often noticed only after permanent damage has been done.

A PTS can be the result of a series of temporary threshold shifts, each of which weakens the hair cells in the cochlea. The cumulative effect of the temporary shifts can be that the hair cells are actually destroyed. At this point, recovery is not possible. The lower decibel sounds never again can be heard. After the first permanent hearing loss has been detected, further hearing losses can occur so long as there continues to be exposure to damaging noise at higher levels.

No one can predict when a Temporary Threshold Shift will become a Permanent Threshold Shift. Our ears can warn us, however, when the danger of permanent hearing damage from relatively short exposure to intense noise is imminent.

Warning Signals

Warning signals, such as a ringing in the ears ("tinnitus"), a threshold shift which lasts more than a few hours or a tickling sensation in the ears (which actually is a mild form of pain) tell us that we should remove oursslves from exposure to high intensity noises or suffer the consequences. These warning signals also tell us that, before returning to the proximity of the high intensity noises, we should take steps to protect our hearing.

Unfortunately, permanent hearing loss often can result from long-term exposure to noise levels which are below the range where we perceive warning signals. It takes longer for hearing to be damaged by noise at these lower levels, but the result is just the same.

Regardless of whether we have been receiving warning signals of hearing damage, hearing tests should be part of a routine physical examination. A hearing test can detect the early signs of a hearing loss and can alert us to a problem before more serious damage occurs.

HOW NOISE DAMAGES HEARING

How intense must noise be before it has the potential to damage our hearing, on either a temporary or a permanent basis? There is no simple definitive answer to this question. There are too many variables involved.

Four Major Variables

The four most important variables are:

1. the level of the sound, as measured in decibels
2. the length of time to which we are exposed to the sound
3. the number and length of quiet (recovery) periods between periods of sound
4. our personal sensitivity to or tolerance for sound.

The danger that noise poses to our hearing is a function of the interaction of these four variables.

Sound Level

Let us examine the first variable, the level of the noise.

- For most persons the threshold of hearing occurs near 0 decibels, usually between 0 and 10 decibels.
- Sounds below approximately 40 decibels are considered low intensity noises. Examples include the rustling of leaves, a whisper and the ticking of a watch.

- Sounds between 40 and 70 decibels are considered moderate in intensity and include such things as conversational speech, a typewriter and the singing of birds.
- Sounds between 70 and 90 decibels are considered loud and include such things as a television, a dishwasher and a table saw.
- Sounds between 90 and 100 decibels are considered intense and include such things as a gasoline-powered lawnmower, a rock band and an emergency siren.
- Sounds between 110 and 130 decibels may induce pain in the ears. Examples include nearby thunder, sonic booms and jet plane takeoffs.

It is at the higher decibel levels (80—90 and above) that the likelihood of noise-induced hearing damage begins to increase if an individual is exposed to noise at or above these levels for a sufficiently long period of time.

Machinery in the industrial/vocational educational shop produces these higher decibel noises. Some examples include:

Machine	dB
Punch Press	96—108
Hydraulic Press	130
Circular Saw	105
Wood Planer	98—110
Oxygen Torch	121

Time Exposure

The second variable affecting potential hearing damage is the time variable. The higher the intensity of the noise, the shorter the time required for hearing damage to occur.

OSHA Standards

The Occupational Safety and Health Administration (OSHA) within the U.S. Department of Labor has established standards for occupational noise exposure. These standards describe the lengths of time beyond which a worker should not be exposed to noise at various levels of intensity during a normal eight-hour working day.

The following table describes the permissible sound exposures established by OSHA.

Hours per Day of Exposure	A-Weighted Sound Level, dB
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

Reprinted from *General Industry OSHA Safety and Health Standards (29 CFR 1910.95).* U.S. Dept. of Labor, November 1978.

Note that in this table sound level is designated "A-weighted." A-weighting is a sound measurement technique which filters out the low frequency sounds which the human ear does not hear well, thus roughly simulating the sensitivity of the human ear to sound frequency.

The table indicates that workers should not be exposed to a sound level which exceeds 90 dB on the average, for an eight-hour day. If such exposure cannot be avoided, steps must be taken to protect the worker's hearing.

The table also indicates that workers should not be exposed to a sound level which exceeds 115 dB, on the average, for even fifteen minutes of a work day. Clearly, workers should never be exposed to steady sound levels above 115 dB.

It should be noted that the OSHA standards presented in this table apply only to working environments. Our hearing is affected by the totality of the noise that we are exposed to in our daily lives.

Recovery Periods

This brings us to a third variable which determines how noise can damage hearing: the number and length of quiet (recovery) periods between periods of sound.

If we do work in a noisy environment in which it is possible to experience threshold shifts, we must avoid extended contact with noisy environments outside of our work. Using power shop tools or lawnmowers or attending rock concerts will not allow our hearing to recover from the effects of day-long noise exposure.

EPA Recommendation and Goal

Another government agency concerned with the protection of all citizens from the damaging effects of noise has recommended lower levels of safe noise exposure. The Environmental Protection Agency (EPA) recommends that, for an eight-hour work day, workers should not be exposed to A-weighted noise levels averaging greater than 85 dB.

The EPA goal exceeds its recommendation. Its goal is to reduce that A-weighted noise level to an average no greater than 75 dB for an eight-hour work day. Further, the EPA believes that, over an entire 24-hour day, individuals should not be exposed to A-weighted noise levels averaging greater than 70 dB. This means that, if a worker is exposed to an average 75 dB while at work, the noise exposure for the sixteen-hour balance of the day should be low enough to bring the overall 24-hour average noise exposure down to the 70 dB level.

The lower noise exposure goals of the EPA are designed to protect public health and welfare under a wide range of situations, and they contain what the EPA believes is an adequate margin of safety for hearing.

Individual Differences

The difficulty in stating precisely what an adequate margin of safety should be for all persons in all types of jobs brings us to the fourth variable affecting potential hearing damage, individual differences. Because all of us differ from one another in various ways, including hearing, safe level of noise exposure for one person may not be safe for another. The fact that others may not report any hearing difficulty resulting from work in a noisy environment does not mean that a given individual will not suffer hearing damage in the same environment.

NOISE CONTROL

In general, there are three basic ways to control noise:

1. at its source
2. along its path
3. at the point of hearing through the use of protective equipment.

Control of noise at its source is probably the best approach. The reason, quite simply, is that, if a piece of equipment or a tool is operating or is made to operate at a safe noise level, there is no hearing danger posed and no need to use additional approaches to noise control.

If source control is not possible, the next best approach is to control the noise along its path. Such control limits the number of persons exposed to the noise. However, it does not always eliminate the noise problem for all persons affected, especially those working directly with or very near the noise source, and it often requires that new noise control steps be taken whenever equipment is moved or work sites are changed.

The use of ear protection equipment is not as desirable as either source control or path control. It affords protection only to those on or near the site who are wearing the equipment, and students must be willing to wear hearing protectors whenever they are exposed to potentially dangerous noise. Further, certain conditions and activities can reduce the effectiveness of the hearing protectors themselves.

SOURCE CONTROL

Source control begins with a careful analysis of the noise-producing equipment, to isolate the major sources of noise within the equipment and to determine how the noise is being transmitted from these sources. The major noise source may be an engine or a motor, but the noise itself may be transmitted as vibration other parts of the equipment which, in turn, radiate the noise heard outside the equipment. In source control, both the major noise source and the secondary noise radiators must be examined and quieted to the greatest extent possible.

The U.S. Environmental Protection Agency has outlined some specific applications of source control. These are listed in Appendix A following this unit. Briefly stated, they include the following:

1. Reduce impact noise.
2. Reduce speed of moving and rotating parts.
3. Reduce pressure and flow velocities in circulating systems.
4. Balance rotating parts.

5. Reduce friction in rotating, sliding, and moving parts.
6. Reduce flow resistance in circulation systems.
7. Isolate vibration within equipment.
8. Reduce the size of the surface radiation and noise.
9. Apply vibration-damping materials to vibrating parts and surfaces.
10. Reduce the leakage of noise from within equipment.

Approaches to control of noise at its source are simple and logical. Approaches such as these should constitute our first line of defense against noise produced by equipment and tools.

In situations where source control measures will not work or such methods will not lower the noise level to a safe point, control of noise along its path to the ear must be considered.

PATH CONTROL

In path control we attempt to block or reduce noise before it reaches our ears. This can be done by

1. containing or enclosing the noise
2. absorbing the noise along its path
3. deflecting the noise away from our ears
4. separating the noise from the hearer.

The approach that is chosen depends on the type of equipment or tool and the environment in which we are working.

Enclosing Noise

Reducing the leakage of noise from within equipment is a basic approach which applies both to source control and path control. Enclosing a noisy piece of equipment in a box or a room or covering a noisy pipe with a heavy sound-absorbing material can effectively quiet noise. Obviously, this may not be practical for highly mobile equipment. But for noisy equipment that is stationary or infrequently moved, it should be considered.

Absorbing Noise

Absorbing noise is another approach common to both source control and path control. Sound-absorbing materials or acoustic lining in a box or room can be used to enclose equipment noise. Noise transmitted from its source through ducts, pipes or electrical channels can be reduced through the use of sound-absorbing materials. The inside surfaces of these noise passageways can be lined with glass fiberboard, and the ducts, pipes or channels can be wrapped with a glass fiber blanket. Baffles constructed of glass fiberboard can be installed inside the noise passageways.

Deflecting Noise

Screens or barriers can be used to deflect the noise that is generated by equipment and tools. Much noise can be literally "walled-in" by barriers which surround the noise source. This can be aided by lining the barriers—which may be wood or metal panels—with sound-absorbing material.

But barriers do not have to surround the noise source to be effective in reducing noise transmission. If it is sufficiently large, a free-standing wall between the noise source and a hearer can reflect much of the noise and create a noise "shadow" to protect the hearer.

Separating Noise and Hearer

Putting distance between the noise source and the persons exposed to the noise is a simple and effective approach to path control. The further away from the noise source we work, the lower the noise level we receive.

PROTECTIVE EQUIPMENT

The need for personal hearing protection arises when source control and/or path control are not present, when source and/or path control do not lower noises to safe levels, or when a worker cannot avoid direct exposure to noisy equipment and tools. There are three basic types of personal protective hearing devices:

1. Disposable pliable materials, such as fine glass wool, mineral fibers and wax-impregnated cotton, may be inserted in the ear. It must be fresh each day. Though such material offers some level of hearing protection, it does not provide the same benefits as do other devices.

2. Ear plugs may be inserted in the ear. These must be individually fitted to the wearer.

3. Cup-type protectors—like ear muffs—may be worn with the band over the head or around the back of the neck or may be incorporated into safety helmets.

The amount of noise protection afforded by these devices varies from one device to another at different sound frequencies. Although it is difficult to generalize for all of the devices available commercially, the wearer of a hearing protection device may expect noise reduction ranging from 10 dB to over 40 dB at certain frequencies. Hearing protective devices will be discussed further in Unit 14.

MANAGEMENT OF NOISE CONTROL

While source control, path control and control at point of hearing are generally accepted as the three basic approaches to noise control, there is a fourth factor which directly affects the need for these three approaches and the amount of noise to which students and instructors are exposed. This fourth factor may be termed the management of noise control.

The management of noise control refers to the administrative decisions that are made to purchase certain types of equipment and tools, to use certain procedures and to schedule work during certain parts of the work period.

Purchasing

It is obvious that the purchase of equipment can affect the noise level on a work site. If relatively noisy equipment is purchased, the noise exposure will be higher, and the need for source, path and point-of-hearing controls will be greater.

Opportunities for decisions which have positive effects on noise control present themselves whenever a piece of equipment or a tool becomes damaged, worn out or obsolete and must be replaced. Decisions to replace equipment and tools with the quietest models available should, over time, result in a much quieter and safer shop.

Procedures

Decisions to choose certain work procedures over others can also affect noise levels in some obvious ways. For example, if material can be either welded or riveted, the choice of welding would result in less noise generation. If concrete can be mixed off the site as well as on, the decision to mix off the site would result, obviously, in less noise on the site.

When noise is generated may be as important a consideration as how much noise is generated. While this approach may be difficult in the industrial/vocational education environment, it may be possible to alter schedules for some noisy operations in order to minimize the number of persons exposed to high noise levels. Decisions also can be made to schedule noisy procedures for several short periods of time during a day or over a number of days rather than in one long, continuous period.

CHEMICAL AGENTS

Having completed our examination of biological and physical agents, we come to the third category of health hazards, chemical agents.

Defining Chemical Hazards

Chemical hazards may be defined as "chemicals thay may, under specific circumstances, cause injury to persons or damage to property because of reactivity, instability, spontaneous decomposition, flammability or volatility."[2] Under this heading are included substances, mixtures or compounds which are explosive, corrosive, flammable or toxic.

Explosives are substances, mixtures or compounds which can enter into a combustion reaction so rapidly and violently that they can cause an explosion.

Corrosives can destroy living tissues. Their destructive effect on other substances, particularly on combustible materials, may result in a fire or explosion.

Flammable liquids are those liquids with a flash point of 100°F (38°C) or less. As we saw in the previous unit on fire protection, combustible liquids (those with flash points above 100°F) also may be hazardous.

Toxic chemicals are those gases, liquids or solids which, through their chemical properties, can produce injurious or lethal effects upon contact with body cells.

PROCESSES AND OPERATIONS WHICH INVOLVE TOXIC AND CORROSIVE AGENTS

Work in the industrial/vocational education shop requires processes and operations where contact with hazardous materials is inevitable. Four examples are metalworking, electroplating, painting and staining and the cleaning of metal parts.

Metalworking

Metalworking inevitably produces fumes and dust. Fumes are very small particles formed by the vaporization of metal during torch-cutting, burning or welding operations, whereas metal dust is generated by grinding. Special precautions such as exhaust ventilation and the wearing of respirators and eye protection need to be taken when cutting, burning or grinding scrap containing alloys of the more toxic metals, such as lead, zinc, cadmium or beryllium.

Electroplating

Electroplating processes, used extensively for decorative purposes and for producing tarnish-resistant finishes, involve hazards of skin contact and inhalation. Because the skin may be exposed to strong acids and alkalis, emergency eye wash and shower facilities are required. Because mists or gases from plating solutions represent a respiratory hazard if dispersed into the air of the workplace, ventilation is required.

Chromic acid is used in chrome plating. Skin contact causes dermatitis and burns known as "chrome holes." The major hazard to health, however, is the inhalation of chromic acid mist or vapor, which causes irritation of the upper respiratory passages and may result in perforation of the nasal septum. Industrial poisoning has occurred from inhaling the mist of solutions containing as little as five percent chromic acid. Local exhaust ventilation should be used with all chromic acid tanks.

Copper plating baths are both acid and alkaline types. The cyanide salts in the alkaline bath are the greatest hazard in copper plating. These salt particles may become airborne when the tanks are charged. Cyanide solutions are readily absorbed, and skin contact must be avoided. Local exhaust ventilation systems are required to draw off the vapors, respirators may be needed, and workers must limit skin contact through the use of gloves which the cyanide cannot penetrate. Good personal hygiene practices must be stressed, including frequent washing of exposed skin areas, particularly before eating or smoking. If a cyanide salt solution is mixed with acid, deadly hydrogen cyanide gas can result. All traces of acid must be rinsed away from parts before they are immersed in the cyanide vat.

Zinc and cadmium plating operations also use cyanide baths. As with copper plating, care must be exercised to avoid contact with the cyanide solution and to prevent a cyanide/acid mix.

Painting and Staining

Painting and staining are two of many industrial/vocational education shop processes which use solvents. Whenever solvents are used, health hazards are present.

What is a solvent? It is a material used to dissolve another material. Although the physiological effects of different solvents vary, generally they include:

1. dermatitis
2. irritation of the respiratory tract

3. interference with the central nervous system.

Skin contact with solvents may cause dermatitis, ranging in severity from a simple irritation to actual damage to the skin. Even the most inert solvents can dissolve the natural protective barriers of fats and oils, leaving the skin unprotected. When these natural lubricants are removed, the skin becomes subject to disabling and possibly disfiguring dermatitis and the way to serious infection is opened. Some of the newer paints contain hardeners and other additives that can cause skin rashes.

Students sometimes wash their hands in such solvents as mineral spirits and turpentine. These solvents take the fats out of the skin, increasing the chance for skin rashes. In some cases, they can be absorbed through the skin. Students must be instructed in specific procedures for cleanliness. They should remove with waterless hand cleaners any paints or stains which get on their skin. Solvent-resistant gloves and long-sleeved shirts worn while painting will prevent the paints or stains from contacting the skin in those areas.

Another principal mode of exposure to solvents is the inhalation of vapors. Such exposure may result in throat irritation and bronchitis and eventual damage to the blood, liver, kidneys and respiratory and gastrointestinal systems. Engineering controls (e.g., ventilation), good work practices and personal protection devices limit such exposures.

All organic solvents affect the central nervous system. Depending upon the degree of exposure and the solvent involved, these effects may range from mild narcosis to death from respiratory arrest. Because solvents act as depressants and anesthetics, they can cause drowsiness and loss of coordination, increasing the risk of accidents. Thinners used in most paints will have a narcotic effect on students, and long-term exposure may cause irreparable liver and lung damage. Respirators should be worn in the spray area or paint booth, and ventilation should be provided.

Cleaning Metal Parts

Strong corrosive solutions are used for cleaning metal parts in dip tanks, reusable filters, etc. When such caustics are used, controlled procedures are necessary. Because skin contact will cause severe burns, rubber gloves and a face shield or goggles should be worn when handling caustics. Any caustics that contact the skin must be washed off immediately. A safety shower and eye wash fountain should be installed where caustics are handled.

Table 16 describes the hazards implicit in some other processes and operations common to the industrial/vocational education shop.

TABLE 16

INDUSTRIAL/VOCATIONAL EDUCATION OPERATIONS AND THEIR ASSOCIATED HEALTH HAZARDS

Abrasive Machining. An abrasive machining operation is characterized by the removal of material from a workpiece by the cutting action of abrasive particles contained in or on a machine tool. The workpiece material is removed in the form of small particles and, whenever the operation is performed dry, these particles are projected into the air in the vicinity of the operation.

Ceramic Coating. Ceramic coating may present the hazard of airborne dispersion of toxic pigments plus hazards of heat stress from the furnaces and hot ware.

Dry Grinding. Dry grinding operations should be examined for airborne dust, noise and ergonomic hazards.

Forming and Forging. Hot bending, forming or cutting of metals or nonmetals may have the hazards of lubricant mist, decomposition products of the lubricant, skin contact with the lubricant, heat stress (including radiant heat), noise and dust.

Gas Furnace or Oven Heating Operations (Annealing, Baking, Drying, Etc.). Any gas or oil fired combustion process should be examined to determine the level of by-products of combustion that may be released into the workroom atmosphere. Noise measurements should also be made to determine the level of burner noise.

Grinding Operations. Grinding, crushing or comminuting of any material may present the hazard of contamination of workroom air due to the dust from the material being processed or from the grinding wheel.

High Temperatures from Hot Castings, Unlagged Steam Pipes, Process Equipment, Etc. Any process or operation involving high ambient temperatures (dry-bulb temperature), radiant heat load (globe temperature) or excessive humidity (wet-bulb temperature) should be examined to determine the magnitude of the physical stresses that may be present.

Molten Metals. Any process involving the melting and pouring of molten metals should be examined to determine the level of air contaminants of any toxic gas, metal fume or dust produced in the operation.

Open-Surface Tanks. Open-surface tanks are utilized by industry for numerous purposes. Among their applications can be included the common operations of degreasing, electroplating, metal stripping, fur and leather finishing, dyeing and pickling. An open-surface tank operation is defined as "any operation involving the immersion of materials in liquids, which are contained in puts, tanks, vats or similar containers." Excluded from consideration in this definition, however, are certain similar operations such as surface-coating operations and operations involving molten metals for which different engineering control requirements exist.

Paint Spraying. Spray painting operations should be examined for the possibility of hazards from inhalation and skin contact with toxic and irritating solvents and inhalation of toxic pigments. The solvent vapor evaporating from the sprayed surface may also be a source of hazard, because ventilation may be provided only for the paint spray booth.

Plating. Electroplating processes involve risk of skin contact with strong chemicals and in addition may present a respiratory hazard if mist or gases from the plating solutions are dispersed into the air of the shop.

Vapor Degreasing. The removal of oil and grease from metal products may present hazards. This operation should be examined to determine that excessive amounts of vapor are not being released into the shop atmosphere.

Welding–Gas or Electric Arc. Welding operations generally involve melting of a metal in the presence of a flux or a shielding gas by means of a flame or an electric arc. The operation may product gases or fumes from the metal, the flux, metal surface coatings or surface contaminants. Certain toxic gases such as ozone or nitrogen dioxide may also be formed by the flame or arc. If there is an arc or spark discharge, the effects of radiation and the products of destruction of the electrodes should be investigated. These operations also commonly involve hazards of high potential eletrical circuits of low internal resistance.

Wet Grinding. Wet grinding of any material may product possible hazards of mist, dust and noise.

Adapted and reprinted from Compliance Operations Manual, U.S. Department of Labor, OSHA 2006, January 1972, pp. XIII-3-8.

Toxic and Corrosive Agents

Many other toxic and corrosive agents are used in various shop operations. Appendix B to this unit contains brief descriptions of the following: aluminum, antimony, arsenic, asbestos, benzene, cadmium, carbon monoxide, chromium, chlorinated hydrocarbon solvents, cobalt, epoxy resins, fluorides, hydrochloric acid, iron oxide, lead, lime, magnesium, manganese, mercury, nitrogen oxide, nitrogen dioxide, nitric acid, oxalic acid, ozone, phosgene, refrigerants, silicon dioxide, sulfuric acid and zinc.

LABELING HAZARDOUS MATERIALS

Functions of Labeling

Information concerning all hazardous materials used in the industrial/vocational education shop should be available to instructors and students alike. Proper labeling is a fundamental part of a safe and effective operation. Labeling has two principal functions:

1. adequate identification—what the material is and where it came from

2. precautionary information for safe handling of all chemicals having significant material hazard.

Purchased materials always have either the chemical or common name of the materials, the name of the manufacturer and a lot number. If the chemical is flammable, a flash point may be shown on the label accompanied by a precaution regarding fire hazard. If the material is corrosive, toxic, reactive or unstable, other precautionary information is usually shown.

Absence of precaution on the label does not necessarily mean that there is no hazard. Some manufacturers are not diligent in providing such information, and some purchasing agents are not conscientious in channeling information to the shop instructor and supervisor.

Absent Labels

Absence of labels can be very dangerous. When hazardous materials are found in containers with no identifying label or with a label illegible from contact with chemicals, such containers must be removed until they can be identified and labeled. If such identification cannot be made, the material should be disposed of. Liability suits often are based on inadequate labeling of a material involved in an accident. Good labeling practice helps protect the teacher and school from such litigation.

Federal Hazardous Substances Act

The Federal Hazardous Substances Act, now administered by the Consumer Product Safety Commission, requires precautionary labeling on all flammable, corrosive, reactive, toxic or radioactive substances intended for non-industrial use.

U.S. Department of Transportation

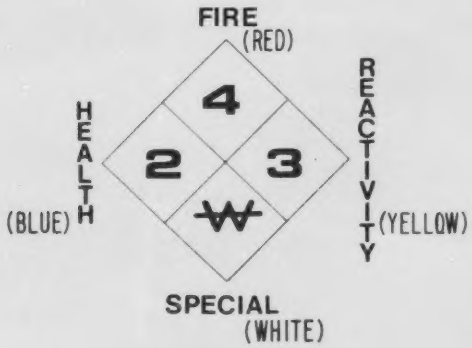
The U.S. Department of Transportation requires certain shipping labels on packages of hazardous materials carried interstate.

Occupational Safety and Health Act

The Occupational Safety and Health Act has a general duty clause requiring an employer to provide a safe place of employment. Unlabeled or inadequately labeled hazardous materials could be construed as a violation of this act.

NFPA Standard System

The National Fire Protection Association, in its NFPA 704M, Standard System for the Identification of the Fire Hazards of Materials, has developed a popular hazardous materials identification system. The NFPA System relies on a diamond-shaped diagram divided into four parts (see Figure 29).



Adapted from NFPA 704M, Standard System for the Identification of the Fire Hazards of Materials, 1979, *National Fire Codes*, and reprinted with permission.

Figure 29

The top segment indicates the flammability hazard and is colored red. The segment to the left of the fire hazard indicates the health hazard of the material and is colored blue. The segment to the right of the fire hazard indicates the reactivity hazard and is colored yellow. The bottom segment is reserved to identify special information of which the user should be aware. For example, a W with a line drawn through it (~~W~~) indicates unusual reactivity with water. Oxidizing chemicals are identified by an OXY in the bottom segment, and radiation hazards are identified with the radiation symbol.

The hazard rating for each category of hazard pertaining to a given material is indicated by a number in the appropriate segment. The number scale ranges from 0 to 4, with materials designated as 0 presenting little or no hazard and materials designated as 4 presenting extreme hazard (see Table 15). It should be noted that the health hazard designations refer only to the immediate acute effects of exposure to the chemical. The chronic long-term health effects are not taken into account.

What meaning do the health hazard designations have for industrial/vocational education operations? Because materials designated 4 and 3 present extreme danger, it is most unlikely that they will be present in the shop. A2 indicates materials which are hazardous to health; their use requires a full-faced mask which provides eye protection and a self-contained breathing apparatus. A1 indicates materials where a self-contained breathing apparatus (e.g., an approved canister type gas mask) may be desirable. A0 indicates that persons working with the material require no special clothing.

The NFPA hazard symbol is a method by which the instructor and student can see at a glance the dangers presented by a particular substance. It helps to ensure proper storage and use of chemicals and solvents. Some manufacturers include the diagram on their labels. In order to make his own hazard symbol, the instructor will need to refer to label statements and detailed Material Safety Data Sheets (see Appendices C and D).

Perhaps the major limitation to the NFPA system is that it does not identify the specific chemical involved, only what hazards it represents.

NIOSH Identification System

The National Institute for Occupational Safety and Health (NIOSH) has a system which incorporates the NFPA Standard

TABLE 15

NFPA HAZARD CODING SYSTEM

Identification of Health Hazard Color Code: BLUE		Identification of Flammability Color Code: RED		Identification of Reactivity (Stability) Color Code: YELLOW	
	Type of Possible Injury	Susceptibility of Materials to Burning		Susceptibility to Release of Energy	
Signal		Signal		Signal	
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given.	4	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.	4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3	Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given.	3	Liquids and solids that can be ignited under almost all ambient temperature conditions.	3	Materials which in themselves are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given.	2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	2	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given.	1	Materials that must be preheated before ignition can occur.	1	Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.
0	Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.	0	Materials that will not burn.	0	Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

Reproduced with permission from NFPA 704, Standard System for the Identification of the Fire Hazards of Materials, 1979, National Fire Codes.

while providing more specificity (the trade or chemical name) and more detail. In a criteria document entitled *An Identification System for Occupational Hazardous Materials*, NIOSH recommends that the label contain the following:

1. the trade name or chemical name of the product
2. a hazard symbol consisting of three rectangles containing terse indications of a relative health hazard, fire hazard and reactivity hazard
3. appropriate statements on the nature of the hazard
4. appropriate action statements
5. emergency action and first aid statements
6. cleanup and disposal statements where appropriate.

Adoption of this or a similar system by OSHA would standardize labels for industry and for other users of reagent chemicals. Examination of each part of the recommendation shows that the first part provides what the NFPA system does not, the trade or chemical name of the product. The second part incorporates the NFPA hazard symbol just discussed.

The remainder of the recommendations are label statements. Such statements convey more information than the hazard symbol and less information than the Material Safety Data Sheet which is also part of the NIOSH criteria documents. Appendix C to this unit contains details about Recommendations 3 through 6:

1. label statements on the
    a. nature of the hazard (health, fire and reactivity)
    b. action necessary to protect against the hazard
2. label statements concerning first aid
3. label statements concerning cleanup and disposal.

The NIOSH document also contains a Material Safety Data Sheet, a form by which manufacturers transmit hazard information to users (see Appendix D). It contains relevant information about the physical and toxicological properties of the chemical. Labels generally list only the major components of chemical reagents or solvent mixtures. Therefore, the instructor must depend on the data sheet for information about chemical components which, though minor, may be toxic or dangerous.

Most manufacturers and suppliers have developed information sheets similar to the NIOSH form. At the time that hazardous materials are purchased, the manufacturer should be asked to furnish such toxicity and hazard information. The forms which are provided should be distributed to instructors, supervisors, maintenance personnel and members of the Shop Safety and Health Committee.

Other Label Information

In addition to the six NIOSH recommendations, labels for industrial/vocational education use should contain:

1. the manufacturer's name and the lot number of the chemical

2. the age of the material.

The first item is important because manufacturers sometimes need to recall batches of chemicals. When the manufacturer's name is on the label, the substance under question can be located quickly. Because some chemicals become unstable or ineffective with age, it is also necessary to identify the purchase date.

It may not be practical to put all the desired information on the label, especially if the container is small. The instructor must use his good judgment in selecting what information should appear. The most essential item is the chemical or product name, which never should be omitted. Figure 30 is a sample label which includes the information discussed in this section.

DISPOSAL OF HAZARDOUS MATERIALS

The NIOSH criteria document deals in its last section with the disposal of hazardous materials. Toxic and hazardous wastes can be both difficult and expensive to get rid of.

The disposal of hazardous materials is strictly regulated by law in many states. When an instructor orders students to dump hazardous materials into the sink and to flush them down or to pour toxic materials onto the ground, he may be violating applicable state or municipal laws. Municipal, state and federal laws all regulate the discharge of toxic and hazardous materials into sewage systems and receiving waters and the atmosphere.

Health Hazards

CHEMICAL NAME						
FORMULA				FLASH POINT		
KINDS OF HAZARDS	CORROSIVE TO SKIN AND EYES ___			FLAMMABLE ___		
	TOXIC BY INGESTION ___			REACTIVE WITH WATER ___		
	TOXIC BY INHALATION ___			UNSTABLE ___		
	TOXIC BY SKIN CONTACT ___			RADIOACTIVE ___		

SEVERITY OF HAZARDS	HEALTH	0	1	2	3	4
	FIRE	0	1	2	3	4
	REACTIVITY	0	1	2	3	4
	SPECIFIC					

EMERGENCY TREATMENT

SUPPLIER

DATE PREPARED _____ PURCHASED _____ RECEIVED _____

USAGE

OTHER INFORMATION

From *Safety in the School Science Laboratory,* NIOSH, August 1977, p. W-8-35.

Figure 30

Industrial/vocational education shops have two basic disposal alternatives open to them. They can handle the disposal themselves, or they can pay a commercial disposal service. The first alternative is time-consuming, and the second is relatively expensive.

For assistance in learning what regulations apply to the shop and what disposal alternatives are best suited to their situation, instructors and supervisors should seek the help of such resources as the Environmental Protection Agency and other appropriate local and state government offices.

TOXICITY
Toxicity vs. Hazard

The toxicity of a material is not identical with its quality for being a health hazard. Toxicity is the "capacity of a material to produce injury or harm." Hazard is "the possibility that exposure to a material will cause injury when a specific quantity is used under certain conditions."[3] The key elements to be considered when evaluating a health hazard are

1. the amount of material required to be in contact with a body cell in order to produce an injury
2. the total time of contact necessary
3. the probability that the material will be absorbed or come in contact with body cells
4. the rate of generation of airborne contaminants
5. the control measures in use.

Not all toxic materials are hazardous. The majority of toxic chemicals are safe when packaged in their original shipping containers or contained in a closed system. As long as toxic materials are adequately controlled, they can be used safely.

For example, many solvents, if not used properly, will cause irritation to eyes, mouth and throat. They are also intoxicating and can cause blistering of the skin and other forms of dermatitis. Prolonged exposure may cause more serious illness. But, if the solvents are used in a well-ventilated area and the person is provided with protective equipment which prevents the substance from coming in contact with skin, then they can be used without being a hazard.

In this case, certain controls—ventilation and protective equipment—have enabled the person to use the solvent while minimizing the risk of illness. However, it must be understood that nontoxic materials should be substituted for toxic ones whenever possible.

Acute and Chronic Effects

The toxic action of a substance can be divided into acute and chronic effects:

- *Acute effects.* These involve short-term high concentrations which cause illness, irritation or death. They are the result of sudden and severe exposure, during which the substance is rapidly absorbed. Usually acute effects are related to an accident, which disrupts ordinary processes and controls. For example, sudden exposure to a high concentration of zinc oxide fumes in the welding shop can cause acute poisoning.

- *Chronic effects.* These involve continued exposure to toxic substances over long time periods. When the chemical is absorbed more rapidly than the body can eliminate it, accumulation in the body begins. Since the level of contaminant is relatively low, effects, though serious and irreversible, may go unnoticed for long periods of time. For example, breathing even low concentrations of carbon monoxide for long periods of time can cause damage to the heart muscles and blood vessels.

SOURCES OF INFORMATION

Frequently accidents involving hazardous materials occur in the shop because neither the instructor nor the student knows or is able to anticipate the effects of a particular chemical combination or the toxicity of a chemical compound. One of the primary goals of any shop safety and health program should be to minimize the frequency and severity of accidents which result from a lack of knowledge.

Incompatible Chemicals

Information about chemical reactions and incompatible chemical compounds and elements should be used by instructors whenever necessary to prevent bodily injuries and property damage resulting from unexpected chemical reactions. Table 13 in the previous unit listed some chemical incompatibilities. The following publications should be consulted in case of doubt about a particular reaction and are excellent sources of information on hazardous chemical reactions.

Manufacturing Chemists Association, *Guide for Safety in the Chemical Laboratory*, 2nd ed., Van Nostrand Reinhold Company, New York, New York. 1972.

Meyer, E., *Chemistry of Hazardous Materials*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 1977.

National Fire Protection Association, NFPA 49, Hazardous Chemicals Data 1979, *National Fire Codes*, Boston, Massachusetts. 1979.

National Fire Protection Association, NFPA 591M, *Manual of Hazardous Chemical Reactions* 1975, Boston, Massachusetts. 1975.

Stecher, P. G., ed., *The Merck Index*, 9th ed., Merck & Co., Inc., Rahway, New Jersey. 1976.

Steere, N. V., ed., *Handbook of Laboratory Safety*, 2nd ed., The Chemical Rubber Co., Cleveland, Ohio. 1971.

Chemical Toxicity

Though safety hazards have been the subject of concern among industrial/vocational educators for many years, many of the common chemicals found in shops have been largely ignored though they may present significant health hazards. For example, both benzene and asbestos have been designated as potential carcinogens.

The following publications in addition to *The Merck Index* already cited, contain information on the toxicities of chemical compounds. The proper interpretation of toxicity information and data may require expertise that is beyond that ordinarily possessed by industrial/vocational education instructors. Expert advice should be sought when needed either through the appropriate state officials or through the National Institute for Occupational Safety and Health.

Casarett, L. J. and J. Doull, eds., *Toxicology: The Basic Sciences of Poisons*, Macmillan Publishing Co., Inc., New York, New York. 1975.

Key, Marcus M., ed., *Occupational Diseases: A Guide to Their Recognition*, revised ed., U.S. Department of Health, Education, and Welfare, DHEW (NIOSH) 77-181, June 1977.

1978 Registry of Toxic Effects of Chemical Substances (RTECS), U.S. Department of Health, Education, and Welfare, NIOSH, Rockville, Maryland, GPO Stock Number 017-033-00346-7, $13.00. Available only from: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

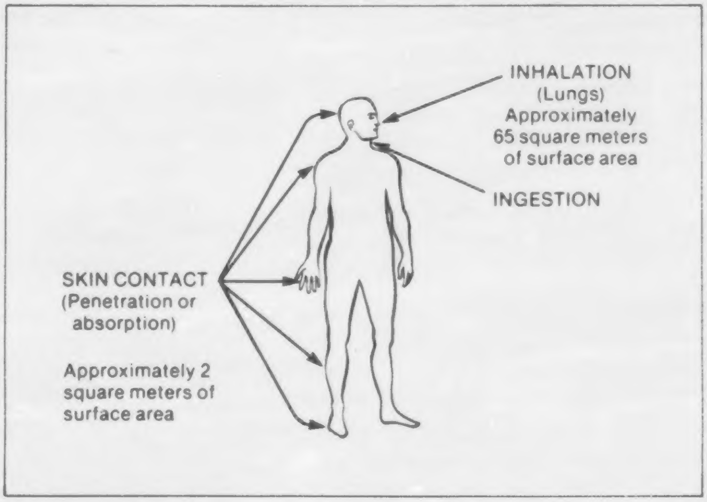
Sax, N. I., *Dangerous Properties of Industrial Materials*, Van Nostrand Reinhold Company, New York, New York. 1975.

MODES OF ENTRY FOR TOXIC MATERIALS

In order for a hazardous substance to exert its toxic effect, it must come into contact with a body cell. There are three modes of entry for chemical compounds in the form of liquids, gases, mists, dusts, fumes and vapors:

1. ingestion (through the mouth)
2. skin absorption
3. inhalation (through the lungs).

Each of these modes of entry will be examined, with particular attention paid to dermatitis from skin contact and respiratory ailments arising from inhalation of toxic chemicals.


INHALATION
(Lungs)
Approximately
65 square meters
of surface area
INGESTION
SKIN CONTACT
(Penetration or
absorption)
Approximately 2
square meters of
surface area

Adapted and reprinted with permission from Robert J. Firenze, *The Process of Hazard Control*, Kendall/Hunt Publishing Co., Dubuque, Iowa 52001, 1978, p. 423.

INGESTION AS A MODE OF ENTRY

Of the three modes of entry, ingestion is the least common. A harmful amount of toxic material can be swallowed accidentally, but this is not common. Far greater is the likelihood of a student ingesting toxic materials because of careless washing before eating, drinking or smoking.

Inhaled toxic dusts can also be ingested in amounts that may cause trouble. Particles in inspired air which are insoluble in the mucous of the respiratory tract may be carried to the mouth where they are either spit out or swallowed. If they are readily soluble in body fluids, toxic materials can be absorbed in the digestive system and picked up by the blood.

The fact that a substance has been swallowed does not necessarily mean that it will be absorbed. A certain selectivity tends to prevent absorption of unnatural substances or to limit the amount absorbed through the walls of the digestive tract. Materials not absorbed are eliminated directly through the intestinal tract. Food and liquid in the digestive tract dilute the toxic substance and may react with it to produce a harmless or insoluble substance. If the toxic substance is absorbed by the bloodstream, it will pass to the liver, which may alter and detoxify it but possibly be damaged itself in the process.

The basic detoxification process involves the following steps:

1. deposit in the liver
2. conversion to a nontoxic compound
3. transportation to kidney by way of the bloodstream
4. excretion through kidney and urinary tract.

SKIN ABSORPTION AS A MODE OF ENTRY

The second mode of entry for hazardous materials is through skin absorption. Some substances are absorbed by way of the openings for hair follicles; others dissolve in the fats and oils of the skin. Of all occupational diseases, skin ailments are the most frequent. Dermatosis is the name given to any disease of the skin; dermatitis refers to any inflammation of the skin.

Anatomy of the Skin

The skin is composed of two layers: the epidermis and the dermis. The epidermis is of primary concern in the occupational dermatoses.

The first layer of the epidermis is the lipid or fatty surface, sometimes called the acid mantle because it has an acid pH and the capacity to buffer certain weak alkaline substances. This lipid surface is composed of oil and sweat and is easily washed off.

Under the thin layer of lipids lies the stratus cornea or keratin layer. This layer is the chief barrier against water and aqueous solution and provides fair protection against attack by chemicals except for alkalis. Because it is composed of dead skin cells, this layer is constantly being replaced by new cells pushing to the surface from the deeper layer of the epidermis, the germinative layer.

The dermis, or "true skin," is tough and resilient. It contains connective tissue and, if injured, can form new tissue to repair itself. The dermis is the main natural protection against trauma.

Causes of Skin Irritation

There are five important causes of occupational dermatoses:

1. plants
2. biological agents
3. physical agents
4. mechanical agents
5. chemical agents

Although the emphasis in this unit is on the chemical agents, we will briefly examine the other causes.

Plant Poisons

Plant poisons which can cause dermatitis are produced by several hundred plants, of which the best known are poison ivy, poison oak and poison sumac. Dermatitis from these three sources may result from bodily contact with clothing or other objects which previously have been exposed to the poison. Some woodworking shops have reported cases of dermatitis when students were working with West Indian mahogany, silver fir and spruce, especially when sandpapering and polishing.

Biological Agents

Biological agents which cause dermatitis may be bacterial, viral, fungal or parasitic. These are not often encountered in industrial/vocational education shops.

Physical Agents

Physical agents which lead to dermatosis include heat, cold and radiation. Hot water softens the skin so that substances attack it more readily. X-rays and other ionizing radiation may cause dermatosis, severe burns and even cancer. Prolonged exposure to sunlight, the most common source of sun-damaging radiation, produces skin changes which may cause dangerous body alterations.

Mechanical Causes

Mechanical causes of skin irritation include friction, pressure and trauma, including abrasions. If the horny layers of the skin become softened by such mechanical causes or by high temperatures and excessive perspiration, dermatosis may result. Friction may result in abrasion or, more commonly, a callus.

CHEMICAL AGENTS

In industrial/vocational education shops chemical agents are the most frequent cause of dermatoses. Such chemicals can be divided into two groups: primary irritants and synthesizers.

Primary Irritants

Primary irritants react on contact, altering the chemistry of the skin. Such irritants cause a chemical reaction which may vary from complete destruction to burning to inflammation or irratation. About 80 percent of all occupational dermatoses are caused by primary irritants. The following are the broad categories of primary irritants. Many of the specific substances are discussed in detail in Appendix B, Examples of Toxic and Corrosive Chemicals.

Organic solvents irritate the skin because of their solvent qualities. They remove the natural oil from the skin, leaving it dry, scaly and subject to cracking and infection. Examples of such organic solvents are trichloroethylene, acetone and petroleum distillates used for degreasing and hand cleaning operations.

Detergents also remove the natural oils from the skin or react with the oils of the skin to increase susceptibility to chemicals which ordinarily do not affect the skin. Such detergents include the alkalis and soap.

Dessicators, hygroscopic agents and anhydrides take water out of the skin and generate heat. Examples are sulfuric acid, potash and sulfur dioxide.

Protein precipitants tend to coagulate the outer layers of the skin. Examples of protein precipitating agents are alcohol, tannic acid, formaldehyde and phenol and such heavy metal salts as the salts of arsenic, chromium, mercury and zinc.

Oxidizers unite with hydrogen and liberate nascent oxygen on the skin. Examples include chromic acid, hydrogen peroxide, chlorine and ozone.

Sensitizing Agents

Some chemical substances produce no irritation on initial skin contact. After repeated or extended exposure, however, some individuals will develop an allergic reaction termed sensitization dermatitis. A once-immune person suddenly may develop an allergic reaction to a particular substance.

This allergic reaction may come in the form of small pimples or water blisters and look like contact dermatitis. However, the skin reaction may occur at a site quite different from that where contact occurred. The difficulty comes in determining just what agent is causing the sensitization. Once a person has become sensitized to a given material, the only sure way to prevent future allergic reactions is to avoid the product in the future. In some cases medication and desensitization by a physician may be a solution.

Typical sensitizers include some epoxy resin amine hardeners, certain metals (e.g., chromium, nickel) and coal tar derivatives.

Some substances act as both primary irritants and sensitizing agents. These include such organic solvents as turpentine and the chlorinated phenols, chromic acid, formaldehyde and epoxy resin components.

Appendix E lists some chemical causes of dermatoses and indicates which are primary irritants and which are sensitizers.

PREVENTING DERMATOSIS

The best way to control dermatosis is to prevent skin contact with the offending agents. Where possible, chemicals of low toxicity and irritant potential should be substituted. Contact can be minimized by good personal hygiene, personal protective equipment and barrier creams.

Good Personal Hygiene

Frequent and thorough washing with appropriate cleansers removes irritating substances before they can cause trouble. Students should be told where, how and when to wash and should be advised that they will be rated on this part of their performance.

Wherever solvents are used, good personal hygiene is important. Spills and splashes should be cleaned up immediately with soap and water. Clothing which has been splattered by chemical solvents should be replaced with clean clothing.

Contact with Acids

In the case of local contact with acid, the most important treatment is immediately to wash the affected area with large amounts of water. For minor contact, such as a splash on the hand, running water from a tap may be sufficient, provided enough time is allowed for complete removal of the acid. In the case of large area contact, readily accessible, well-marked, rapid-action safety showers are required, and a minimum of fifteen minutes should be devoted to removing all traces of acid.

Eye-Wash Fountain

A special eye-washing fountain or bath also should be provided. Adequate time for removal of acid should be allowed. This may necessitate repeated fifteen-minute washings while medical attention is being sought.

Choosing a Soap

The type of soap used is important. Even a generally good soap may cause irritation on certain types of skin. According to the National Safety Council, a soap should:

1. be freely soluble in hard or soft, cold or hot water
2. remove fats, oils and other soil without harming the skin
3. leave the natural fats and oils in the skin
4. contain no harsh abrasives or irritant scrubbers
5. be handy to use if in cake form or flow easily through soap dispensers if in granulated or powder form
6. stay insect-free
7. retain its properties in use.[4]

Students sometimes contract dermatitis by washing their hands in the wrong kinds of solutions. They should not be permitted to use solvents, even if they may feel that these cleaning agents are the easiest to use and work the fastest. They should be required to use the soap-dispensing units provided.

Personal Protective Equipment

To keep dermatitis-causing agents from contact with the skin, the student may need impermeable protective clothing such as aprons, face shields and gloves. But the student must be aware that many solvents can penetrate rubber or neoprene gloves. Neoprene protects against most common oils and aliphatic hydrocarbons, but neither it nor rubber offers protection against the aromatic and halogenated hydrocarbons, the ketones and many other solvents. For such uses polyvinyl alcohol gloves provide protection, but these gloves must be kept away from water, acetone and other solvents.

Regular periodic cleaning and drying of gloves is as important as using the proper type. Any equipment that cannot be decontaminated should be discarded.

Barrier Creams

Barrier creams are the least effective way of protecting the skin. They are not a substitute for gloves, except where there is only occasional and minor contact with a solvent. Barrier creams and lotions should be used to supplement good personal hygiene and personal protective equipment. Three main types of barrier creams and lotions are available:

1. vanishing cream, which contains soap and emollients that coat the skin and cover the pores to make subsequent cleanup easier
2. water-repellant types (e.g., lanolin, petrolatum, organic silicones), which leave a water-insoluble film on the skin and thus repel water-dissolved irritants
3. solvent-repellent types (e.g., methyl cellulose, sodium silicate and tragacanth), which are insoluble in oils and solvents.

Barrier creams should be applied to clean skin. When the skin becomes soiled, both the cream and soil should be washed off and the barrier reapplied.

INHALATION AS A MODE OF ENTRY

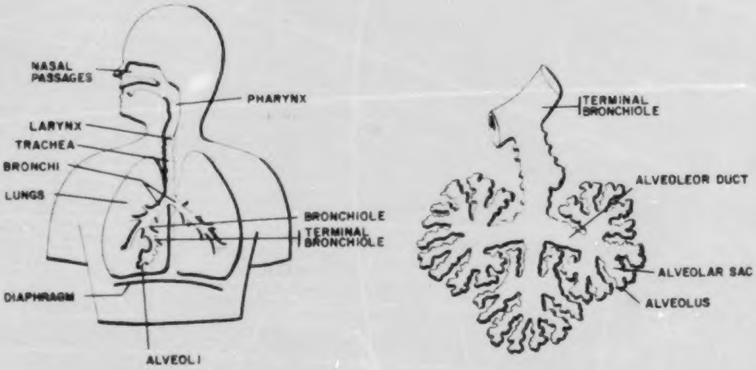
Up to now we have examined ingestion and skin absorption as modes of entry. The third mode of entry for chemical agents is inhalation. It is a particularly important mode of entry because of the rapidity with which a toxic material can be absorbed in the lungs, pass into the bloodstream and reach the brain. Had the same material been ingested instead of inhaled, it would have been considerably diluted with the contents of the stomach. Inhalation hazards arise from excessive concentration of mists, vapors, gases or solids that are in the form of dusts or fumes.

ANATOMY OF RESPIRATORY SYSTEM

Parts of the Respiratory System

The respiratory system consists of three main parts (see Figure 31):

1. air passages or airways, including the nose, mouth, upper throat, larynx, trachea and bronchi
2. the lungs, where oxygen is passed into the blood and carbon dioxide is given off
3. the diaphragm and the muscles of the chest, which permit normal respiratory movement.


NASAL PASSAGES
PHARYNX
LARYNX
TRACHEA
BRONCHI
LUNGS
BRONCHIOLE
TERMINAL BRONCHIOLE
DIAPHRAGM
ALVEOLI
TERMINAL BRONCHIOLE
ALVEOLEOR DUCT
ALVEOLAR SAC
ALVEOLUS

Reprinted from *A Guide to Industrial Respiratory Protection* Cincinnati: NIOSH, 1976), p. 10.

Figure 31

How the Respiratory System Works

The respiratory system brings air containing oxygen into the lungs where oxygen transfers to the blood. The oxygen-enriched blood travels to all parts of the body to sustain life. At the same time carbon dioxide transfers from the blood to the lungs and then out of the system. The system that delivers the air to the alveoli is extremely important to the healthy functioning of the lungs.

Nasopharyngeal Passages

The nasopharyngeal passages serve as a heat exchanger and humidifier, warming and moisturizing inhaled air so that it will not constitute a shock to the delicate lung tissues. Some particles are removed by nasal hairs (cilia), at bends in the air path and by sedimentation.

These passages, as well as the trachea and bronchial tubes are covered with mucous membranes. The mucus secreted by these membranes gives up heat and moisture and serves as a trap for particulate contaminants before they can reach the lungs. It also dilutes irritating substances.

Bronchioles

The bronchi branching from the trachea divide into smaller and smaller bronchioles, forming an increasingly difficult route of entry for particulate matter. The respiratory bronchioles lead into several ducts, each of which ends in a cluster of air sacs, the alveoli.

Oxygen transfer takes place in the alveoli. These minute sacs are like clusters of grapes covered with a network of blood capillaries. The alveolar walls are membranes through which gases and even aerosols can pass easily. Through the thin walls of the alveoli, the blood takes on oxygen and gives up its carbon dioxide in the process of respiration.

RESPIRATORY HAZARDS

Depending upon the solubility of the material, inhalation of chemical agents may irritate the upper respiratory tract, including the mucous membranes, or it may harm the terminal passages of the lungs and air sacs. Inhaled contaminants fall into three general categories:

1. particulates which, when deposited in the lungs, may produce rapid local tissue damage, slower tissue reaction, disease or physical plugging (e.g., asbestos fiber)
2. toxic vapors and gases that produce adverse reaction in the tissue of the lungs (e.g., hydrogen fluoride)
3. toxic vapors and gases that do not affect the lung tissue locally but may either
    a. pass from the lungs into the bloodstream, where they are carried to other body organs (e.g., cadmium oxide fumes, solvents)
    b. affect adversely the oxygen-carrying capacity of the blood cells themselves (e.g., carbon monoxide).

Dusts

Dusts are solid particles generated by handling, crushing, grinding, rapid impact, detonation and breaking apart by heating of organic and inorganic material. Dust normally contains a wide range of particle sizes, with the small particles greatly outnumbering the large ones. Consequently, when dust is noticeable in the air near an operation, probably more invisible dust particles than visible ones are present. A process which produces dust fine enough to remain suspended in the air long enough to be breathed should be regarded as hazardous unless it can be proved safe.

Respiratory System as a Dust Collector

The respiratory tract, with its successive branches and passageways, is a highly efficient dust collector. All particles which enter the respiratory system and are smaller than four or five microns are deposited somewhere in the system. Larger particles—those greater than two microns in size—are deposited for the most part in the upper respiratory system: the nasal cavity, trachea, bronchial tubes and other air passages. Intermediate particles are deposited about equally in the upper respiratory system and in the alveolar or pulmonary air spaces. Smaller particles—one micron or less in size—are generally deposited in the alveolar spaces. Figure 32 shows the sizes of various airborne contaminants.

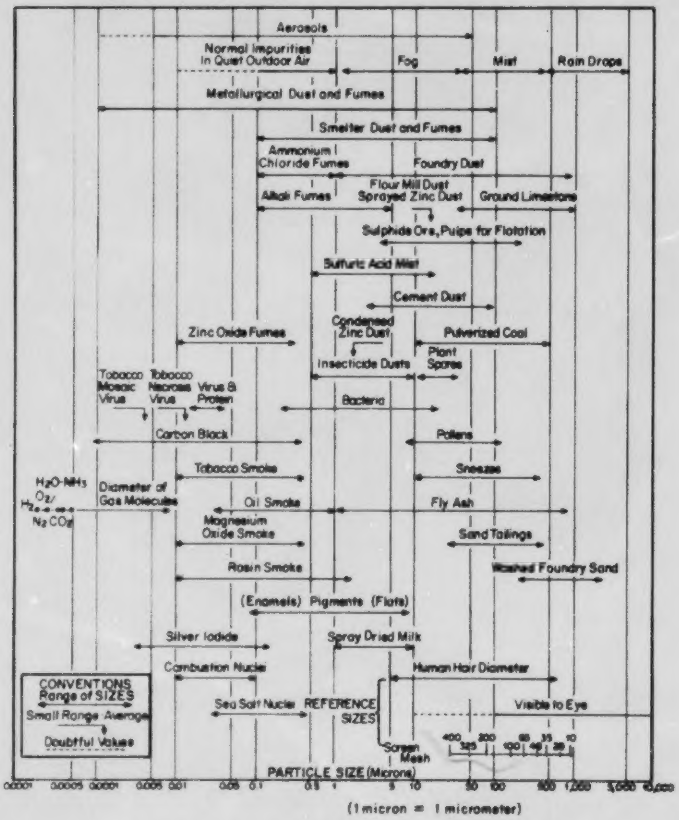


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Figure 32

Fumes

Fumes are forms of particulate matter which differ from dusts only in the way they are generated and in their particle size. A fume consists of extremely small particles, less than a micron in diameter, and is generated by such processes as combustion, condensation and sublimation.

Arc welding volatizes metal vapor that condenses—as the metal or its oxide—in the air around the arc. These fumes, because they are extremely fine, are readily inhaled. Toxic fumes formed when welding galvanized metal may produce severe symptoms of toxicity. Either the fumes must be controlled by the local exhaust ventilation, or the welder must be protected by respiratory equipment.

To evaluate dust and fume exposures properly requires knowledge of

- the chemical composition
- particle size
- concentration in the air
- length of exposure time.

Potential Health Hazards

Potential health hazards from dust and fumes occur on three levels:

1. Regardless of its chemical composition, the inhalation of sufficient quantities of dust can cause a person to choke or cough.
2. Depending upon its chemical composition, the dust can cause allergic or sensitization reaction in the respiratory tract or on the skin.
3. Depending upon both its size and chemical composition, the dust can damage vital internal tissues.

Appendix B at the end of this chapter discusses the dangers of the following dusts and fumes: aluminum, antimony, arsenic, asbestos, chromium, fluorides, iron oxide, lead, magnesium, manganese, silicon dioxide and zinc oxide (including metal fume fever).

Gases Affecting Lung Tissue

Gases are formless fluids that expand to occupy the space in which they are confined. Examples are arc welding gases, sulfur dioxide, phosgene, ozone and nitrogen dioxide. Vapors are the volatile form of substances that are normally in the solid or liquid state at room temperature and pressure.

Potential Health Hazards

Some highly reactive gases and vapors of low solubility can produce an immediate irritation and inflammation of the respiratory tract. They can cause chemical pneumonia and pulmonary edema. When lung tissue is burned, the injured tissue pours out fluid from the bloodstream. When this fluid accumulates in the lungs, oxygen exchange cannot take place and suffocation occurs. This condition is known as pulmonary edema.

THRESHOLD LIMIT VALUES

Individual susceptibility to respiratory toxins is difficult to assess. Nevertheless certain safe limits can be established.

Definition

A Threshold Limit Value (TLV) refers to airborne concentrations of substances and represents an exposure level under which most people can work, day after day, without adverse effect. Because of wide variations in individual susceptibility, however, an occasional exposure of an individual at or even below the threshold limit may not prevent discomfort, aggravation of a preexisting condition or occupational illness.

The term TLV refers specifically to limits published by the American Conference of Governmental Industrial Hygienists. These TLV limits are reviewed and updated each year. Appendix A-1 of *Fundamentals of Industrial Hygiene*, 2nd ed. (Chicago: National Safety Council, 1979), contains the 1978 ACGIH TLVs. There are three categories of Threshold Limit Values.

Time-Weighted Average

1. Time-Weighted Average (TLV-TWA) is the time-weighted average concentration for a normal eight-hour day or forty-hour week. Nearly all persons may be exposed day after day to airborne concentrations at these limits without adverse effect.

Short-Term Exposure Level

2. Short-Term Exposure Limit (TLV-STEL) is the maximal concentration to which persons can be exposed for a period of up to fifteen minutes continuously without suffering:

   a. irritation

   b. chronic or irreversible tissue change

c. narcoses of sufficient degree to increase accident proneness, impair self-rescue or materially reduce work efficiency. No more than four fifteen-minute exposure periods per day are permitted, with at least sixty minutes between exposure periods.

Ceiling

3. Ceiling (TLV-C) is the concentration that should not be exceeded even instantaneously.

The following points should be kept in mind when dealing with TLVs:

1. Concentrations of chemicals rarely remain constant in the shop throughout a school day.
2. Most industrial/vocational education environments contain mixtures of chemicals rather than single compounds.
3. Because individual susceptibilities vary, control measures must be provided for those persons whose sensitivity places them outside the average.

Federal Occupational Safety and Health Standards

The first compilation of health and safety standards from the U.S. Department of Labor's OSHA appeared in 1970. Because it was derived from then-existing standards, it adopted many of the TLVs established in 1968 by the American Conference of Governmental Industrial Hygienists.

Permissible Exposure Levels

Thus Threshold Limit Values—a copyrighted trademark of the American Conference of Governmental Industrial Hygienists—became, by federal standards, Permissible Exposure Limits (PELs). These PELs represent the legal maximum level of contaminants in the air of the workplace.

The General Industry OSHA Standards as they were in effect on November 7, 1978, are summarized in OSHA Publication 2206. There are about 400 substances for which exposure limits have been established. These are included in Subpart Z, Toxic and Hazardous Substances, Sections 1910.1000 through 1910.1500.

Most of these exposure limits are tabulated in section 1910.1000. Tables Z-1 and Z-3 in this section were originally part of the 1968 TLV list of ACGIH. These limits already had been adopted by the U.S. Department of Labor under provisions of the Walsh-Healey Act before passage of the OSH Act of 1970. Table Z-2 contains limits developed by the American National Standards Institute (ANSI). Sections 6(a) and 4(b) of the OSH Act gave OSHA authority to promulgate these previously established standards without the hearings and waiting periods required in Section 6(b). This authority ended in April 1973, two years after the effective date of the act.

Sections 1910.1001 through 1910.1500 give more detailed standards regarding individual substances. These standards have been developed in conformance with Section 6(b) of the OSH Act. They have been contested by the affected parties in many cases in the U.S. Courts of Appeals. Some of the substances included in this group are asbestos, vinyl chloride, inorganic arsenic, acrylonitrile, cotton dust and coke oven emissions.

Information about the procedures by which standards are developed, promulgated and enforced can be found in *Crisis in the Workplace*, by Nicholas Ashford (Cambridge, Mass.: MIT Press, 1976).

Section 1910.1000 is reproduced in full as Appendix A-2 in *Fundamentals of Industrial Hygiene*, 2nd ed. (Chicago: National Safety Council, 1979). This text also has chapters on air sampling and industrial toxicology.

Controlling Respiratory Hazards

The methods of controlling respiratory hazards include those that have been outlined for controlling other health hazards in the industrial/vocational education shop: substitution, isolation, housekeeping, personal protective equipment and ventilation. These will be discussed later in this unit.

APPRAISING HEALTH HAZARDS

Before recommendations for controls can be made, a thorough evaluation of health hazards is mandatory. Health hazard evaluation proceeds in two stages:

Preliminary Survey

1. *A preliminary survey* is made to determine which operations and environmental physical agents may be hazardous.

Detailed Study

2. *A detailed study*, including the use of air sampling and direct reading instruments, is made to determine:
   a. the amount of air contaminants present
   b. the extent of exposure to physical agents.

These studies usually are made by an industrial hygienist or others specifically trained in this field. However, the skilled industrial/vocational supervisor and instructor can be of valuable assistance to the industrial hygienist.

PRELIMINARY SURVEY

A preliminary survey is the first step in evaluating the shop environment. Following this procedure can save time and effort. By visual inspection, an experienced person can indicate those operations or conditions for which detailed studies are needed.

During this survey, processes and operations may be observed in which potentially harmful materials are handled, or equipment may be used in a manner that could result in excessive concentrations. The preliminary survey should include such consideration as:

1. general sanitation
2. raw materials, products and by-products
3. physical agents
4. control measures in use.

General Sanitation

One of the best guides on the subject of general sanitation is ANSI 24.1, Minimum Requirements for Sanitation in Places of Employment. This publication contains definitions of general requirements on waste disposal, housekeeping, ventilation and so on.

Raw Materials and Products

New substances and materials which require close evaluation to asssss their potential health hazard are constantly being introduced. It is important to have a list of all substances and materials used in the school. The information will be obtained from the purchasing agent or the manufacturer. After the list is obtained, it is necessary to determine which of the materials are toxic and to what degree. Only when the toxicity and hazardous properties of the substances are known can the necessary safeguards be installed.

Physical Agents

The preliminary survey should note sources of radiant heat, abnormal temperature and humidity, excessive noise, improper or inadequate illumination and X-rays and gamma rays. The use of special instruments is necessary properly to evaluate these potential hazards.

Control Measures in Use

The preliminary survey would not be complete unless the types of control measures in use and their effectiveness were noted:

1. local exhaust: effectiveness, hood design, and so forth
2. general ventilation
3. respiratory protection devices
4. protective clothing
5. shielding from radiant or ultraviolet energy.

Serious doubts about the effectiveness of the existing equipment would arise if dust was on the floor, holes were in duct work, fans were not operating and personal protective devices were being used improperly by the students.

The health hazard of a given chemical or physical agent depends on several factors, including:

1. the nature of the substance or agent
2. the intensity of the exposure
3. the duration of exposure
4. individual susceptibility.

The first three items normally will be determined during the preliminary study. The fourth item requires detailed studies.

During the preliminary survey and detailed study, various sampling instruments are used. The general characteristics, use and limitations of these instruments will be explained in a separate supplement.

Where to Start

The first question to answer is, Where does the sampling begin? Should the sample be taken at the students' breathing zone, out in the general air, or at the machine or process that is putting out the toxic gas or dust? The answer is that air at all three sites should be sampled.

Should the sample be taken for two seconds, two hours, or a whole day? A combination of short- and long-term samples is the best way to get representative information.

Major Types of Samples

There are two major types of samples:

Grab Sample

1. *the grab sample* taken over so short a period of time that the atmospheric concentration is assumed to be constant throughout the sample. This usually will be less than five minutes and usually will cover only part of an industrial cycle. Frequently a series of grab samples will be taken in an attempt to define the total exposure.

Long-Term Sample

2. *the long-term sample*, taken over a sufficiently long period of time so that the variations in exposure cycles are averaged. This kind of sample gives peak exposure concentrations only with very sophisticated recording equipment, and then only for certain materials.

Neither the grab nor long-term sample alone is sufficient; a combination of both must be used.

METHODS OF CONTROLLING HEALTH HAZARDS IN THE WORKPLACE

Generally speaking, health hazard control may be grouped into nine classifications:

1. substitution of a less harmful material for one which is dangerous to health
2. change or alteration of a process to minimize worker contact
3. isolation or enclosure of a process or work operation to reduce the number of persons exposed
4. wet methods to reduce generation of dust in operations
5. general or dilution ventilation with clean air to provide a safe atmosphere
6. local exhaust at the point of generation or local dispersion of contaminants
7. personal protective devices
8. good housekeeping, including cleanliness of the workplace, waste disposal, adequate washing, toilet and eating facili-

ties, healthful drinking water and control of insects and rodents

9. training and education.

Substitution

Replacement of a toxic material with a harmless or less toxic one is a very practical method of eliminating a health hazard. In many cases a solvent with a lower order of toxicity or flammability may be substituted for a more hazardous one. For example, carbon tetrachloride can be replaced by such solvents as methyl chloroform, dichloromethane, or a similar substance. Wherever possible, detergent and water cleaning solutions should be considered for use in place of organic solvents.

Process Change

A change in process often offers an ideal opportunity to improve working conditions. In some cases, a process can be modified to reduce the exposure to dust or fumes and thus markedly reduce the hazard. For example, brush-painting or dipping instead of spray painting will minimize the concentration of airborne contaminants from toxic pigments.

Isolation or Enclosure

Some potentially dangerous operations can be isolated from persons who are near. Isolation can be accomplished by a physical barrier (such as sound-absorbing screens to reduce the noise from a piece of machinery), by time (such as providing semi-automatic equipment so that a person does not have to stay near the noisy machine constantly), or by distance (remote controls).

Enclosing the process or equipment is a desirable method of control since the enclosure will prevent or minimize the escape of the contaminant or physical energy into the shop atmosphere.

Wet Methods

Dust hazards frequently can be minimized by application of water or other suitable liquid at the source of dust when better methods, such as vacuum cleaning, cannot be applied.

Ventilation[5]

General ventilation is an effective control for areas generating low concentrations of hazardous substances. It works by adding air to keep the concentration of a contaminant below hazardous levels. It uses either natural convection through open doors, windows, roof ventilators and chimneys or artificial air currents produced by fans or blowers. Exhaust fans through roofs, walls or windows constitute positive all-season dilution ventilation. Consideration must be given to providing make-up air, especially during winter months. Dilution ventilation is practical only when the degree of air contamination is not excessive and particularly when the contaminant is released at a substantial distance from the worker's breathing zone. Under other conditions the contaminated air will not be diluted sufficiently before inhalation.

General ventilation should not be used where there are major, localized sources of contamination, especially highly toxic dusts and fumes. Local exhaust is more effective and economical in such cases. When comparatively small amounts of the less toxic solvents are vaporized, general or dilution ventilation can be a satisfactory method of control.

Several points must be kept in mind when using dilution ventilation:

1. Exhaust openings should be located as close as possible to the source producing the contaminant.
2. To keep the contaminants out of the breathing zone of the student, the fresh air applied to the work space should first pass through the students' breathing zone, then across the work space where the contaminant is produced and into the exhaust system as rapidly as possible.
3. Unless the exhausted air is discharged far away from the fresh air intake duct, the fresh air can become contaminated.

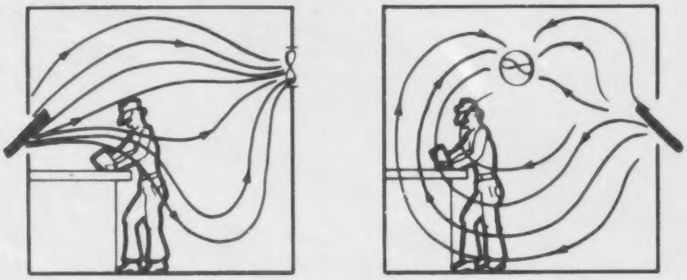
Examples of possible arrangements, both good and bad, for dilution ventilation of work space are depicted in Figure 33.

Local Exhaust Ventilation

Local exhaust ventilation is the most effective means of control for airborne contaminants produced by welding or cutting. A local exhaust system works by trapping the air contaminant near its source so that a student standing near the process is not exposed to harmful concentrations. This method is usually preferred to general ventilation, but should be used only when the contaminant cannot be controlled by substitution, changing the process, isolation or enclosure. Even though a process has been isolated, it still may require a local exhaust system.

After the system is installed and set in operation, its performance should be checked to see that it meets engineering specifications, correct rates of air flow, duct velocities, negative pressures and so

GENERAL VENTILATION

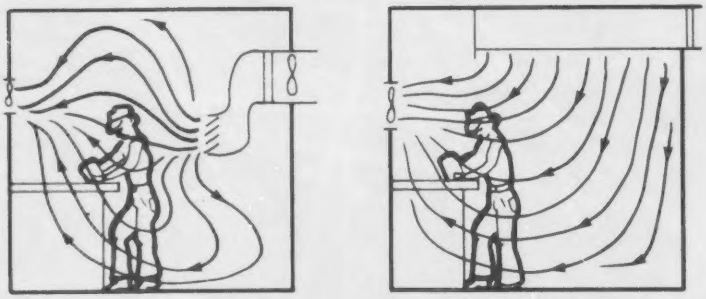


Poor General Ventilation

(Contaminant is driven into the worker's breathing zone and atmosphere)

Fair General Ventilation

(Incomplete flushing of the room; contamination of general atmosphere)



Good General Ventilation

(Air enters at breathing zone height and keep contamination away from worker)

Best General Ventilation

(Low velocity diffusion through ceiling, immediate exhaust of contaminated air)

Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), pp. 29–30.

Figure 33

on. Its performance should be rechecked periodically as a maintenance measure.

Examples of Local Exhaust Systems

Local exhaust ventilation can be provided by several types of equipment, including fixed enclosures (booths), freely movable hoods, and down-draft benches.

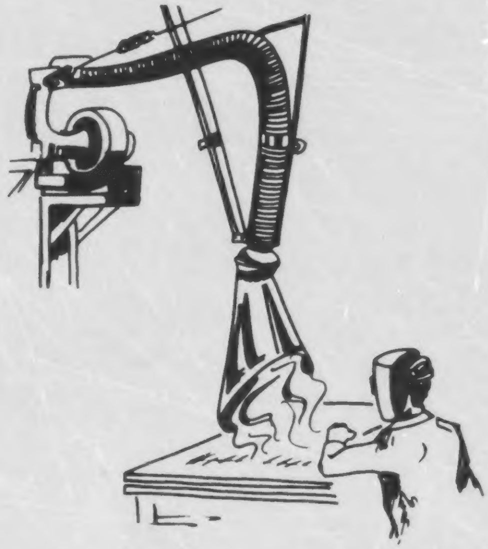
Fixed Enclosures

Fixed Enclosures — Many operations done in a fixed location can be provided with a fixed enclosure. This is a structure built around the operation which has a means for drawing air through the work area so that the work space is flushed continuously with fresh air.

Within such an enclosure, work should be arranged and conducted in such a way that the fresh air enters the enclosure through the student's breathing zone and then passes through the work space in which the contaminants are produced. For most fixed enclosures, the air should move at least 100 feet per minute across the entrance to the enclosure.

Freely Movable Hoods

Freely Movable Hood — This consists of a movable hood, attached to a fan. The fan draws air from the work space and exhausts it outdoors, either directly or through a dust collection system. The hoods normally are constructed so that they can be moved into place by the welder, as illustrated in Figure 34.

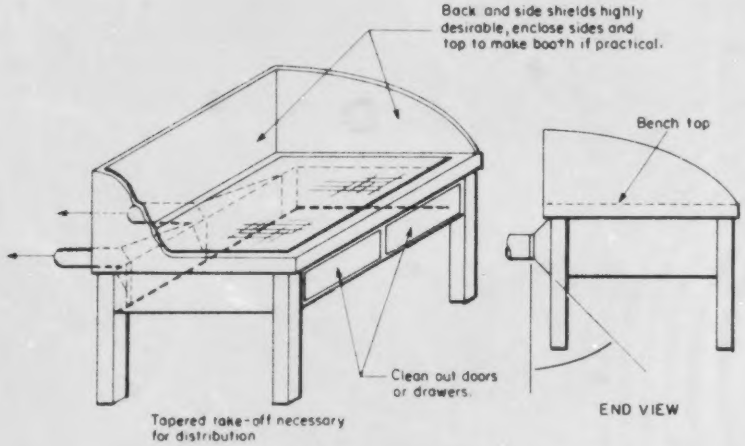


Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 31.

Figure 34

Down-Draft Benches

Down-Draft Benches — Another example of a local exhaust ventilation is the down-draft bench or table. The operation is performed on a bench or table which has an open grid as the work surface. Air is drawn downward through the grid into the duct work and then exhausted, preferably outdoors. This prevents the contaminants from rising into the person's breathing zone. However, to function properly the work being done on the bench must not be of such a size that it covers most of the work surface. This would obstruct the airflow into the exhaust system (see Figure 35).


Back and side shields highly desirable, enclose sides and top to make booth if practical.
Bench top
Clean out doors or drawers.
END VIEW
Tapered take-off necessary for distribution

Typical downdraft bench

Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 33.

Figure 35

Personal Protective Equipment

Personal protective equipment should not be used as a substitute for feasible engineering or administrative controls. However, students who encounter physical and chemical hazards in the industrial/vocational education shop sometimes will need such personal protective equipment as hearing protectors, respirators, and special clothing, (aprons, gloves, etc.). The next unit will be devoted to an examination of the types, uses and limitations of personal protective equipment.

Good Housekeeping

Good housekeeping in the shop goes a long way to reduce health hazards.

Removing dust from ledges and on the floor prevents its dispersion into the shop atmosphere. A regular cleanup schedule using vacuum lines is the most effective method of removing dust from the work area. In the absence of a central vacuum cleaning system, portable vacuum cleaners should be used. An air hose for blowing away dust should not be used.

Good housekeeping is also essential where solvents are stored, handled and used. Leaking containers or spigots should be corrected immediately, either by transferring the solvent to sound containers or by repairing the spigots. All solvent-soaked rags or absorbents should be disposed of in airtight metal receptacles and removed daily from the shop.

Training and Education

Proper training and education are essential supplements to engineering controls. The student must know the proper operating procedures that make engineering controls effective. If he performs an operation away from an exhaust hood, he not only will defeat the purpose of the control but also will contaminate the work area. Since new materials are constantly being marketed and new processes developed, re-education and followup instruction must be part of the training program.

Instructors may include knowledge and practice of environmental controls as one factor in evaluating a student's overall shop performance.

CONCLUSION

The instructor or supervisor who is aware of the health hazards presented by the biological, physical and chemical agents found in the industrial/vocational education shop has taken the first step in limiting these hazards. By applying the control measures detailed in this unit, he can limit the dangers presented by radiation, vibration and noise. He can be sure that chemical agents in the shop are labeled adequately, used carefully and disposed of properly. He can use such engineering controls as substitution, isolation and ventilation to protect against the three modes of entry for hazardous substances.

However, engineering controls are insufficient to protect against some physical and chemical hazards. Therefore, the instructor and supervisor need to understand the uses of personal protective equipment in the shop safety and health program.

NOTES

1. *Understanding Noise and Noise Control,* a publication of the Office of Noise Abatement and Control, U.S. Environmental Protection Agency (June, 1978), serves as the source for much of this section.

2. *Fundamentals of Industrial Hygiene* (Chicago: National Safety Council, 1979), p. 8. The definition of explosives, corrosives, flammable liquids and toxic chemicals are adapted from this source.

3. *Fundamentals of Industrial Hygiene,* pp. 8—9.

4. *Fundamentals of Industrial Hygiene,* p. 221.

5. This discussion on ventilation is adapted from *Safety and Arc Welding and Cutting,* Publication No. 78-138 of the U.S. Department of Health, Education, and Welfare, NIOSH (January 1978), pp. 28–34.

QUESTIONS AND ANSWERS

1. What are the three categories of health hazards?

a. biological agents

b. physical agents

c. chemical agents.

2. What part of the body is most susceptible to radiation hazards?

the eye

3. What is a Permanent Threshold Shift?

A Permanent Threshold Shift is a condition in which a person permanently loses the ability to hear sounds at lower decibel levels.

4. What are the four most important variables which determine whether sound has the potential to damage the hearing?

a. the level of the sound as measured in decibels

b. the length of time that we are exposed to the sound

c. the number and length of quiet recovery periods between periods of sound

d. personal sensitivity to or tolerance for sound.

. . . .

5. What are the three basic ways to control noise?

. . . .

a. at its source

b. along its path

c. at the point of hearing

. . . .

6. What are three health hazards presented by solvents?

. . . .

a. dermatitis

b. irritation of the respiratory tract

c. interference with the central nervous system.

. . . .

7. What are the three modes of entry for toxic materials?

. . . .

a. ingestion

b. skin absorption

c. inhalation

. . . .

8. What is the difference between dermatosis and dermatitis?

. . . .

Dermatosis refers to any disease of the skin; dermatitis refers to any inflammation of the skin.

9. What is the difference between a primary irritant and a sensitizing agent?

Primary irritants react on contact, altering the chemistry of the skin. Sensitizing agents cause an allergic reaction to develop in some persons after repeated or extended exposure.

10. What is a Threshold Limit Value?

A Threshold Limit Value is the exposure level to airborne concentrations of substances under which most people can work, day after day, without adverse effect.

11. There are nine important ways to control health hazards in the workplace. Name six.

Any six from among the following:

a. substitution

b. change or alteration of process

c. isolation or enclosure

d. wet methods

e. general or dilution ventilation

f. local exhaust

g. personal protective devices

h. good housekeeping

i. training and education.

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APPENDIX A

CONTROLLING NOISE AT ITS SOURCE

CONTROLLING NOISE AT ITS SOURCE

Of the three approaches to noise control, source control is preferable to path control or control at the point of hearing. It makes other control methods unnecessary and eliminates the problem for all persons affected. In *Understanding Noise and Noise Control* (June 1978), the U.S. Environmental Protection Agency's Office of Noise Abatement and Control suggests ten ways to control noise at its source. The industrial/vocational education teacher and supervisor will want to apply these suggestions to the school setting.

1. *Reduce impact noise produced when parts of equipment strike one another.* This may be accomplished by:
    a. reducing the size or weight of the impacting mass
    b. reducing the travel of the impacting mass
    c. using small impact force over a longer period, rather than large impact force over a shorter period
    d. cushioning the impact with shock-absorbing material
    e. avoiding the use of metallic material on both impact surfaces
    f. applying smooth acceleration to impact mass.
2. *Reduce speed of moving parts and rotating parts.* This may be accomplished by:
    a. operating motors, turbines, fans and so forth at lowest blade-tip speeds that meet job requirements
    b. using the largest diameter, lowest speed fans that meet job requirements
    c. using centrifugal or squirrel cage fans, which are not so noisy as propeller or vane axial fans.
3. *Reduce pressure and flow velocities in air, gas or liquid circulation systems.* Reducing velocities lessens turbulence which, in turn, reduces noise radiation.
4. *Balance rotating parts.* When shafts, flywheels, pulleys and so forth are not in balance, they cause structural vibration which transmits noise.

5. *Reduce friction in rotating, sliding or moving parts.* When friction is reduced, the smoother operation of parts translates into lower noise levels. Friction is reduced by:

   a. lubricating moving parts

   b. properly aligning moving parts

   c. properly polishing smooth surfaces on moving parts

   d. properly balancing rotating parts

   e. replacing eccentric or out-of-round rotating parts or any worn parts.

6. *Reduce flow resistance in air and liquid circulation systems.* By using large-diameter, low-velocity pipes and ducts and by ensuring that the inside surfaces of the pipes and ducts are smooth and free of obstruction and sharp corners, the flow will be streamlined and lower noise levels will result.

7. *Isolate vibration within equipment.* Steps to follow to prevent a vibrating component from transmitting all of its noise-producing vibration to other parts and surfaces of equipment include:

   a. installing the vibrating components (motors, pumps, fans and so forth) on the most massive part of the equipment

   b. installing the components on vibration-absorbing, resilient mounts

   c. using belt- or roller-drive systems rather than gear trains

   d. using flexible, not rigid, hoses and wiring.

8. *Reduce the size of the surface radiating the noise.* As a rule, the larger the vibrating surface, the greater the noise that is radiated. When vibrating surfaces are reduced in size—for example, by removing excess material, cutting out portions of the surface, or using wire mesh in place of sheet metal—the noise output is reduced.

9. *Apply vibration-damping materials to vibrating parts and surfaces.* The concept of vibration damping is, quite simply, that reducing the vibration reduces the noise. Materials that can be applied to vibrating surfaces include liquid mastics (such as automobile undercoating), pads (such as rubber, felt, adhesive tape, fibrous blankets), and sheet metal laminates or composites. The liquid mastics may be sprayed, the pads may be glued, and the sheet metal laminates may be bonded directly to the vibrating surfaces.

10. *Reduce the leakage of noise from within equipment.* Sealing noise within a piece of equipment is another simple noise control concept. This may involve:

    a. sealing or covering all unnecessary holes and cracks

    b. using gaskets around all electrical and plumbing penetrations

    c. installing lids or shields with gaskets over functional or required openings

    d. using mufflers, silencers or acoustically lined ducts for intake, exhaust, cooling or ventilation openings

    e. directing openings away from the equipment operator, and to the greatest extent possible, away from other workers

    f. using sound-absorbent linings on inner surfaces of equipment

    g. using vibration-damping materials on vibrating inner surfaces of equipment.

APPENDIX B

EXAMPLES OF TOXIC AND CORROSIVE AGENTS

EXAMPLES OF TOXIC AND CORROSIVE AGENTS

Aluminum. In welding and cutting operations, aluminum is a major component of metals and filler metals. The inhalation of aluminum dust or its compounds, including aluminum oxide fumes, is not known to have any adverse health effects.

Antimony. Antimony is used as an alloying metal in many specialty metals. Antimony and its compounds irritate the skin and mucous membranes. Skin contact with antimony can result in a dermatitis which begins as an inflammation of the hair follicles and progresses through pus formation and sloughing to leave a scar. Symptoms of excessive exposure to airborne antimony are a metallic taste in the mouth, vomiting, loss of appetite and general stomach distress. Chronic exposure reduces white blood cells and causes liver damage.

Arsenic. Arsenic may be encountered in welding and cutting operations as a component of various alloys, where it gives increased heat resistance and hardness. Welding or cutting on metals that are painted with arsenic compounds also can be hazardous. Arsenic is a poison that accumulates in the body. It is deposited in many bodily tissues, especially in the liver and kidneys. Fumes and dust produce inflammation of mucous membrane surfaces, irritation of the eyes and exposed skin and a husky voice and cough. Because the effects of arsenic may not appear for weeks, months or even years after exposure, students should be protected from all contact. Because serious skin irritation results from contact with rubber in the presence of arsenic, respirators used for protection should not be made of rubber.

Asbestos. Asbestos may be found in many locations in the industrial/vocational education shop. Hand- and power-operated tools may produce or release asbestos fibers; asbestos pads may be used for welding and soldering; personal protective equipment (aprons, gloves, etc.) may contain asbestos; students repairing brakes or machine linings may be exposed to asbestos. Once asbestos fibers are inhaled, they may remain trapped in the lung, where the body tries to isolate them by producing scar tissue. Long-term exposure to high concentrations of asbestos fibers causes asbestosis, a disease of the lungs, and is thought to cause cancer. The main symptom of asbestosis is shortness of breath. Engineering controls include isolation, enclosure, exhaust ventilation and dust collection. Respirators and special clothing also may be necessary.

Benzene. Benzene (sometimes called benzol, phenyl hydride, coal naphtha) is classified as a flammable liquid as well as a carcinogen. Inhalation of high concentrations can affect the central nervous system. High concentrations of benzene also are irritating to the mucous membranes of the eyes, nose and respiratory tract. Exposure to benzene also can lead to the development of leukemia. Its vapors can form explosive mixtures and burn with a smoky flame.

Because it is one of the two or three most dangerous organic solvents in commercial use, benzene should not be used in the industrial/vocational education shop. It can be replaced with toluene in most lacquers, synthetic rubber solutions and paint removers. Benzene should not be confused with benzine, a petroleum distillate.

Cadmium. Cadmium may be found as a coating on metals in welding shops. Cadmium is used frequently as a rust-preventive coating on steel and also as an alloy. Cadmium-plated or alloy steel may look like zinc-coated steel. Cadmium oxide (CdO), the brownish-yellow fume produced when cutting cadmium-containing metals, can be extremely hazardous.

Excessive cadmium oxide exposure causes no marked initial discomfort. However, acute symptoms occur a few hours later. These symptoms include dry cough, irritation of the throat and tightness of the chest and lead to extreme difficulty in breathing, chest pains and possible death from pulmonary edema (fluid in the air spaces of the lungs). Long-term exposure to low levels of cadmium in the air can result in kidney damage and emphysema. Adequate ventilation must be provided. Respirators and protective clothing offer additional protection.

Carbon Monoxide. Carbon monoxide is a gas usually formed by the incomplete combustion of various fuels. It is commonly found in automotive shops from engine exhaust. Portable gas-filled heaters also produce carbon monoxide, as do internal combustion engines and improperly maintained or adjusted burners and flues. Carbon monoxide is odorless and colorless and cannot be detected by the senses. Common symptoms of overexposure include pounding of the heart, a dull headache, flashes before the eyes, dizziness, ringing in the ears and nausea.

Chromium. Chromium is the primary alloying agent in stainless steel. Some chromium compounds are strong oxidizing agents and are extremely toxic and irritating to the skin, eyes and mucous membranes. Workers exposed to chromium compounds have a death rate from lung cancer 29 times that of the average population. Although welding under normal conditions will not produce hazardous concentrations of chromium compounds, welding of stainless steel should be carried out with adequate ventilation.

Chlorinated Hydrocarbon Solvents. Various chlorinated hydrocarbons (e.g., trichloroethylene, perchloroethylene and carbon tetrachloride) are used in degreasing and other cleaning operations. They may injure the liver, cause dermatitis and depress the central nervous system. Skin contact should be avoided. A respirator should be used so that the vapors will not be inhaled. In welding and cutting operations, the heat and ultraviolet radiation from the electric arc will decompose the vapors of these solvents and form highly toxic and irritating phosgene gas (see Phosgene).

Cobalt. Cobalt appears as an alloying agent in high-strength, high-temperature alloys. Cobalt produces an allergic skin irritation, and inhalation of cobalt fumes can cause shortness of breath and coughing. A common allergic response to cobalt dust is cobalt pneumoconiosis, which can be fatal. Because many workers become sensitized to cobalt at concentrations lower than the legal limit, engineering controls to avoid exposure are necessary.

Epoxy Resins. Materials which should be regarded as hazardous include wet or uncured epoxy resins and the chemicals used to harden, thin, strengthen or make the resin flexible. Dermatitis can result from handling epoxy resins and the chemicals used to manufacture them or from sanding or polishing epoxy surfaces. The use of impervious plastic gloves and similar protection over other skin areas can help prevent this condition. Some of the symptoms of dermatitis include redness, itching, swelling and blisters. Oozing, crusting and scaling of the skin also can occur.

Respiratory irritation, headache, nausea, intestinal upsets and other conditions may result from breathing vapors or dust from the various epoxy manufacturing processes. The eyes also may be affected by vapors or by direct contact.

Fluorides. Fluoride compounds are found in the coatings of several ~~types of fluxes~~ used in welding. Exposure to these fluxes may irritate the eyes, nose and throat and may produce painful skin burns. Repeated exposure over a long period to high concentrations of fluorides in the air may cause pulmonary edema (fluid in the lungs) and bone damage. Prolonged exposure to fluoride dusts and fumes also may cause acute systemic poisoning.

Hydrochloric Acid. Hydrochloric acid is a corrosive substance used in metal work as a flux for soldering galvanized iron. It is also used for electroplating and pickling.

Inhalation of excessive concentrations of hydrochloric acid mist results in irritation of the upper respiratory tract, usually limited to inflammation of the nose, throat and larynx. Fortunately, the pungent, irritating odor gives adequate forewarning of hazard. Ingestion of the acid causes burning of the mucous membranes of the mouth, esophagus and stomach. The major protection should be local exhaust ventilation and enclosure of processes.

Aqueous solutions of hydrochloric acid cause severe skin burns unless promptly removed with water. Dermatitis may ensue upon repeated contact of the skin with diluted solutions of the acid. Protective clothing can prevent contact with the skin, and protective creams can prevent irritation of exposed skin. Prolonged contact with the eyes may result in permanent visual impairment or total loss of sight.

There is no conclusive evidence that hydrochloric acid presents chronic systemic health hazards.

Hydrochloric acid solutions are not flammable. However, solutions of hydrochloric acid attack most metals, evolving hydrogen, which may form explosive mixtures with the air.

Hydrochloric acid solutions must be stored in glass or in rubber-lined containers. These containers should not be stored with or near oxidizing agents, particularly nitric acid and chlorates, nor highly flammable substances. Because of the highly corrosive action on metals, the areas should be well ventilated. Whenever hydrochloric acid is spilled, the area should be washed immediately with a large amount of water. Lime may be used to neutralize spilled acid on concrete, wood or other reactive or absorbing materials.

Iron Oxide. During the welding of steel, iron oxide fumes arise from both the base metal and the electrode. The primary acute effect of this exposure is irritation of nasal passages, throat and lungs. Although long-term exposure to iron oxide fumes may result in iron pigmentation of the lungs, most authorities agree that these iron deposits in the lungs are not dangerous.

Lead. Lead was one of the first industrial materials to be recognized as a serious health hazard. The welding and cutting of lead-bearing alloys or metals whose surfaces have been painted with lead-based paint can generate lead oxide fumes. Inhalation and ingestion of lead oxide fumes and other lead compounds will cause lead poisoning. Symptoms include a metallic taste in the mouth, loss of appetite, nausea, abdominal cramps and insomnia. In time, anemia and a general weakness, chiefly in the muscles of the wrists, develop. Prevention of lead poisoning is almost entirely a matter of good housekeeping and dust control. Ventilation is very important.

Lime. To name but a few of its many uses, lime (quick lime, caustic lime, calcium oxide) is found as a binding material in building materials, a dehydrating agent, a flux in steel manufacturing, and in the manufacture of glass and paper. It is a caustic and rapidly can burn the skin, eyes and upper airways on contact. Inhaling calcium oxide dust can cause chemical pneumonia. If pulverized lime is moistened, it forms calcium hydroxide, which generates heat as well as carbon monoxide and carbon dioxide. Flammable or combustible materials must not be stored near pulverized lime as they may be ignited from the heat produced.

Workers must wear goggles and gloves when handling lime. Eye wash and emergency shower facilities must be available in the immediate area. "Hydrated pulverized lime" may be substituted for pulverized lime as it is not heat-reactive and is therefore less of a fire hazard.

Magnesium. Magnesium and magnesium-aluminum alloys, both found as alloys in steel, are used in the manufacture of structural parts for airplanes and in tool making. Welding and cutting on magnesium-containing metals produce magnesium oxide fumes. Inhalation of these fumes can irritate the eyes, nose and throat and cause metal fume fever (see Zinc). Sometimes printers exposed to fine dusts have a chronic cough.

Manganese. Manganese fumes, released near reduction furnaces and from manganese-coated welding rods, can cause metal fume fever. In most cases, the concentrations of manganese dioxide fumes generated during welding are not hazardous. Nevertheless, cases of manganese poisoning have been reported. Manganism is a severely crippling, permanently disabling disease of the nervous system that closely resembles Parkinson's disease. Early symptoms are weakness, instability, difficulty in walking and monotonous intermittent speech. To avoid the hazards of manganese fumes, welding operations must be well ventilated.

Mercury. Mercury compounds are used to coat metals to prevent rust. Under the intense heat of the arc or gas flame, mercury vapors are produced. Exposure to these vapors may cause stomach pain, diarrhea, kidney damage or respiratory failure. Long-term exposure may produce tumors, emotional instability and hearing damage.

Nitrogen Oxides, Nitrogen Dioxide and Nitric Acid. Nitrogen oxides are used in the pickling and etching of metals. The high temperatures used in processes such as gas and electric arc welding —especially in poorly ventilated areas—can oxidize the nitrogen in the air into the various nitrogen oxides. Exposure may occur during jewelry manufacture, brazing, lithographing, metal cleaning, glass blowing and electroplating. Nitrogen oxides also occur in garages from automobile exhaust.

The nitrogen oxides are extremely irritating to the eyes and upper respiratory tract. Though exposure to concentrations above the threshold limit causes cough and immediate chest pain, lower concentrations can be inhaled without great discomfort. There may be only mild signs of bronchial irritation, followed by a five- to twelve-hour symptom-free period. During this period, the nitrogen oxides have changed into nitrogen dioxide, and the nitrogen dioxide has reacted with the watery atmosphere of the respiratory tract and air sacs to produce nitric acid. The nitric acid burns the lungs and air sacs.

As a response to the burning, the injured tissue pours out fluid from the bloodstream. If this fluid accumulates in the lungs, it interferes with oxygen exchange; the victim may suffocate as a result of pulmonary edema. Even if the victim recovers, he may suffer permanent damage to the small air tubes and sacs, resulting in frequent lung infection, chronic cough and shortness of breath. Repeated low-level exposures probably cause chronic bronchitis.

Nitric acid is both a product and a by-product. A corrosive, it may be used in the industrial/vocational education shop for pickling and etching of metals. Gaseous oxides are formed when nitric acid comes in contact with certain metals—such as copper, brass or zinc—or with certain organic materials—such as wood, sawdust, cloth and paper. These oxides are also present in high concentrations during various processes involving the use of nitric acid. Both nitric acid vapors and the gaseous oxides can destroy tissue on contact by direct chemical action.

Severe and deep burns may be produced by skin contact with either the acid or the concentrated vapor. The eyes are very susceptible to injury, and immediate severe damage, possibly of a permanent nature, can result from contact.

Nitric acid is a nonflammable substance. However, it is a strong oxidizing agent. It reacts vigorously with most metals and may cause spontaneous ignition when in contact with organic materials such as sawdust, wood scraps, shavings and paper. The acid may cause an explosion when in contact with certain easily oxidized chemicals. Under certain circumstances, both the acid and the vapor will react with wood cellulose, cotton and similar organic materials to increase their flammability.

Nitric acid should be stored in its original container. It should be kept well away from combustible materials such as turpentine, carbides, hydrogen sulfide and metallic powders. Nitric acid is corrosive to most metals and most organic materials.

The immediate removal of the acid is essential in the case of accidental spills. A large amount of water should be used if the floors are of wood or if other combustible materials are present.

Oxalic Acid. Oxalic acid is a good reducing agent and is sometimes used for bleaching wood. It has the appearance of lump sugar. It is a strong poison if ingested and can also cause severe burns to the eyes, skin and nasal passages.

Chemical goggles must be worn by persons who handle oxalic acid. Impervious gloves will help to prevent skin contact. Workers should be instructed to wash their hands and faces after handling the acid.

Ozone. Ozone may be found in the industrial/vocational education shop either directly or indirectly. It is used to age wood rapidly, to bleach oils and to dry varnish rapidly. It may be generated by such electrical equipment as copying machines and electronic air filters. It may be the result of electric arc welding, where enough energy is released into the atmosphere to change nitrogen and oxygen into both nitrogen dioxide and ozone. Without ventilation, the ozone concentration in the air gets up to about .06 ppm for flux-covered electrodes, and up to about .5 ppm for barewire, argon-shielded welding of aluminum. (The TLV is .1 ppm.)

Like nitrogen dioxide, ozone is irritating to the eyes and mucous membranes. Breathing ozone in low concentrations (above .05 ppm) may cause dryness of the mouth, headaches, coughing and pressure or pain in the chest, followed by difficulty in breathing. Ozone impairs the sense of smell, disguises other odors, alters tastes and reduces the ability to think clearly. It also depresses the nervous system, slowing the heart and respiration and producing drowsiness and sleep. Excessive exposure may produce pulmonary edema.

General ventilation alone may be sufficient to prevent the accumulation of ozone in inhabited spaces. Enclosures can isolate ozone processes, and respirators may be needed in some situations.

Phosgene. Phosgene is a gas produced whenever a compound containing chlorine comes in contact with a flame or hot metal, as occurs in some types of welding, or with ultraviolet light. Low concentrations are mildly irritating to the eyes, nose, throat and respiratory passages. Skin contact causes dermatitis. Symptoms of slight gassing may occur: dry burning throat, numbness, vomiting, chest pain and cough with phlegm. There may be a shortness of breath.

Phosgene reacts with the moisture in the air passages to produce hydrogen chloride. As with the nitrogen oxides, the reaction to a moderately high exposure is delayed for several hours. When the gas dissolves in the fluid of the lung tissues, it causes severe burns. Large quantities of tissue fluid then flood the lungs, resulting in pulmonary edema.

For this reason, chlorinated solvents should be kept well away from welding operations or any operations in which ultraviolet radiation or intense heat is generated. Ventilation is also necessary.

Refrigerants. Problems which may occur during installation, modification or repair of refrigeration units are leaks and, very infrequently, fire or explosion. Refrigerants may be considered in the following classes:

1. *Nonflammable substances where the toxicity is slight,* such as some fluorinated hydrocarbons (Freon). Although considered fairly safe, these refrigerants may decompose into highly toxic gases (e.g., hydrochloric acid, chlorine, phosgene) upon exposure to hot surfaces (sweating, welding, and so forth) or open flames.

2. *Toxic and corrosive refrigerants* (e.g., methyl chloride and ammonia) may be flammable in concentrations exceeding 3.5 percent by volume. Ammonia is the most common refrigerant in this category and is very irritating to the eyes, skin and respiratory system. If there are large releases of ammonia, the area must be evacuated. Re-entry may be made by wearing appropriate respiratory protective devices and protective impervious clothing. As ammonia

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is readily soluble in water, it may be necessary to spray water in the room via a water mist-type nozzle to lower concentrations of ammonia.

3. *Highly flammable or explosive substances* (e.g., propane, ethylene) must be used with strict controls, safety equipment and administrative controls.

If a refrigerant escapes, action should be taken for removal of the contaminant from the premises. If ventilation is used, exhaust from the floor area must be provided for heavier-than-air gases and from the ceiling for lighter-than-air gases.

Silicon Dioxide. Silicon dioxide (free silica) is found as a constituent in the coatings of several welding rods. It also occurs in a free, finely divided dust as the result of blasting and drilling. Depending on the extent of welding, significant concentrations of airborne free silica can be generated. Long-term exposure to excessive concentrations can lead to silicosis, a development of scar tissues in the lungs which prevents normal breathing. Like asbestosis, silicosis is incurable.

Sulfuric Acid. Sulfuric acid is a strong dehydrating and oxidizing agent often found in pickling operations. It is rapidly destructive to tissues, producing severe burns. Concentrated solutions rapidly destroy any body tissue with which they may come in contact. Contact with the eye will result in almost immediate severe damage. Blindness may result if not promptly treated.

The inhalation of concentrated vapor or mist from hot acid will cause damage to the upper respiratory tract and possibly to the lung tissue. Continued inhalation of mist may cause a chronic inflammation of the upper respiratory tract and chronic bronchitis. Dermatitis may result from repeated contact with dilute solutions.

Sulfuric acid is not flammable. In high concentrations it may cause ignition of combustible materials by contact. The acid reacts with most metals to produce highly flammable hydrogen. The acid in its concentrated form reacts violently with organic materials and water, with evolution of heat. To determine if a hazardous mixture of hydrogen (produced by the action of the acid on metal) and air exists, commercial gas indicators are available.

Containers of acid should be isolated from organic or combustible materials or oxidizers such as nitrates, carbides, chlorates and metallic powders.

Because hydrogen may be generated inside a drum or metal storage tank containing sulfuric acid, all means of ignition should be kept from these containers. Spills should be removed quickly by flushing the contaminated area with a large amount of water or by covering the area with dry sand, ashes or gravel if no water is available. Any remaining traces of the acid should be neutralized with soda ash or lime.

Sulfuric acid is highly corrosive to most metals. NFPA 49, Hazardous Chemicals Data, provides safety information on this acid and others discussed in this appendix.

Zinc and Zinc Oxide. Zinc is used in large quantities in the production of galvanized metal, brass and various other alloys. Inhalation of zinc oxide fumes can occur when welding or cutting on zinc-coated metals. Exposure to these fumes can cause metal fume fever. Symptoms of metal fume fever are very similar to those of common influenza. They include fever (rarely exceeding 102°F), chills, nausea, dryness of the throat, cough, fatigue and general weakness and aching of the head and body. The victim may sweat profusely for a few hours, after which the body temperature begins to return to normal. The symptoms of metal fume fever rarely, if ever, last beyond a few hours. The subject then can return to work without any apparent after effects but with an immunity to the fumes. However, this immunity is lost after a day or two away from the job. Therefore, workers are more susceptible to the onset of metal fume fever on Mondays or on weekdays following a holiday than they are on other days.

APPENDIX C

NIOSH SUGGESTIONS FOR LABEL STATEMENTS

PART I. NATURE OF HAZARDS AND HOW TO PROTECT AGAINST THEM

A. Health Hazards

1. Nature of hazard
2. Actions necessary to protect against hazard

B. Fire Hazards

1. Nature of hazard
2. Actions necessary to protect against hazard

C. Reactivity Hazards

1. Nature of hazard
2. Actions necessary to protect against hazard

PART II. FIRST AID STATEMENTS

PART III. CLEANUP AND DISPOSAL INSTRUCTIONS

PART I — NATURE OF HAZARDS AND HOW TO PROTECT AGAINST THEM

The number of statements used on a label will depend on the hazard the substance presents. Extremely dangerous materials will require extensive warnings and detailed instructions for safe use. The following statements are taken from *An Identification System for Occupationally Hazardous Materials* (U.S. Department of Health, Education, and Welfare, NIOSH, 1974).

A. Health Hazards

The major considerations in determining health hazards are:

- the modes of entry
- the speed of attack
- the effects, whether chronic or acute.

1. Nature of the hazard — The following are the statements recommended by NIOSH to identify on the label the health hazard of a given substance.

   — Fatal if swallowed.
   — Fatal if inhaled.
   — Fatal if absorbed through the skin.
   — Harmful if swallowed.
   — Harmful if inhaled.
   — Harmful if absorbed through the skin.
   — Can cause allergic respiratory reaction.
   — Can cause allergic skin reaction.
   — Vapor (gas) may cause suffocation.
   — Causes eye burns.
   — Causes eye irritation.
   — Causes burns.
   — Causes irritation.
   — Can be fatal or cause blindness if swallowed.
   — Cannot be made nonpoisonous.
   — Repeated absorption can cause bladder tumors.
   — Rapidly absorbed through skin.
   — Inhalation can be fatal or cause delayed lung damage.
   — Harmful if inhaled and can cause delayed lung damage.
   — Can cause delayed effect.
   — Vapor extremely irritating.
   — Extremely irritating gas and liquid under pressure.
   — Gas extremely irritating.
   — Lung injury and burns may be delayed.
   — Contact with water or moist air liberates irritating gas.
   — Contact with acid liberates poisonous gas.

- Contact with water or acid slowly liberates poisonous and flammable hydrogen sulfide gas.
- Liberates gas which may cause suffocation.
- Repeated inhalation or skin contact can, without symptoms, increase hazard.
- Causes severe burns which may not be immediately painful or visible.
- Can cause rash or external sores.
- Can cause burns or external sores.
- Liquid or vapor causes burns which may be delayed.
- May cause eye injury—effects may be delayed.
- Liquid penetrates shoes and leather causing delayed burns.
- May cause sterility.
- May affect unborn children.
- Cancer suspect agent.

2. Action necessary to protect against hazard — The following are the action statements recommended by NIOSH for use on labels of a substance which presents a health hazard.

- Do not breathe dust.
- Do not breathe vapor.
- Do not breathe mist.
- Do not breathe gas.
- Do not get in eyes, on skin or clothing.
- Prevent contact with food, chewing or smoking materials.
- Wash thoroughly after handling.
- Use only in well ventilated area.
- Keep container closed.
- Avoid prolonged or repeated contact with skin.
- Do not enter storage areas unless well ventilated.
- Avoid breathing dust of solution spray or vapor.
- Avoid prolonged or repeated breathing of vapor.
- Use special protective clothing and gloves.
- Wear goggles; neoprene, butyl or vinyl gloves, neoprene shoes or boots; and clean protective outer clothing.
- Wear goggles; neoprene, butyl rubber or vinyl gloves.
- Always wear a self-contained breathing apparatus or full-face airline respirator when using this product.
- Have available emergency self-contained breathing apparatus or full-face airline respirator when using this product.
- Wear respirator approved by NIOSH or the U.S. Bureau of Mines for organic vapor, dust, etc.
- Wear goggles or face shield, rubber gloves and protective clothing when handling.
- Do not wear ordinary rubber protective clothing, including gloves and boots.
- Do not taste.

- This gas deadens the sense of smell. Do not depend on odor to detect presence of gas.
- Use fresh clothing daily. Take hot shower at end of work shift using plenty of soap.
- POISON (with skull and crossbones symbol).
- Avoid exposing women of child-bearing age.

B. Fire Hazards

The major considerations in determining fire hazards are:

- vapor pressure and density
- auto-ignition temperature
- explosive limits
- viscosity
- products of combustion
- extinguishing media

1. Nature of the hazard — The following are the statements recommended by NIOSH to identify on the label the fire hazard of a given substance.

    - Strong Oxidizer — contact with other materials may cause fire.
    - Catches fire if exposed to air.
    - Spillage may cause fire or liberate dangerous gas.
    - Highly volatile.
    - Contact with water or acid slowly liberates flammable gas.
    - Contact with water may cause flash fire.
    - May ignite if allowed to become damp.
    - Heat, shock, or contact with other materials may cause fire or explosive decomposition.
    - Contact with other materials may cause fire or explosion, especially if heated.

2. Actions necessary to protect against hazard — The following are action statements recommended by NIOSH for use on the label of a substance which presents a fire hazard.

    - Keep away from fire, sparks and open flame.
    - Keep from contact with clothing or combustible materials to avoid fire.
    - Drying of this product on clothing or combustible materials may cause fire.
    - Spills on clothing or combustible materials may cause fire.
    - Contents packed under water will ignite if water is removed.
    - Avoid friction or rough handling because of fire hazard.
    - Keep wet in storage—dry powder may ignite by friction, static electricity or heat.

- Wear goggles or face shield and fire-retardant clothing when handling.
- Clothing and vegetation contaminated with chlorate or its solutions are DANGEROUSLY FLAMMABLE. Remove clothing and wash thoroughly in water. Keep persons and animals off treated areas.
- Store in cool place.
- Keep container tightly closed.
- Loosen closure cautiously before opening.
- Store in cool dry place.
- Store in a cool place in original container and protect from direct sunlight.
- In case of fire, stop flow of gas. Use dry chemical or carbon dioxide when necessary to gain access to valve.
- Avoid spillage and contact with moisture or combustion.
- In case of spillage, flush with plenty of water and remove contaminated articles.
- Flush area with water spray.
- In case of fire, smother with dry sand, dry ground limestone or dry powder type materials specially designed for metal powder fires.
- Spillage may cause fire. Do not get on floor. Sweep up and remove immediately.

C. Reactivity Hazards

The major considerations in determining reactivity hazards are the substance's

- sensitivity to detonation by shock or heat
- tendency to rapid polymerization
- reactivity with common substances
- ability to supply oxygen in a fire situation
- other special harmful properties

1. Nature of the hazard — The following are statements recommended by NIOSH to identify on the label the reactivity hazard of a given substance.

    - Powerful oxidizer.
    - Strong oxidizer.
    - Strong acid.
    - Strong caustic (alkali).
    - Causes severe burns which may not be immediately painful or visible.
    - Heat, shock, or contact with other materials may cause fire or explosive, especially if heated.
    - Contact with other material may cause fire or explosive, especially if heated.
    - Reacts violently with water liberating and igniting hydrogen.
    - May form explosive peroxides.
    - Forms shock-sensitive mixtures with certain other materials.
    - May explode if water content is 10% or below.

- Contamination may result in dangerous pressure.
- Liquid and gas under pressure.
- Extremely cold ((F   (C) below zero)).
- High explosive.
- Explosive.
- Inhibited monomer subject to violent polymerization.
- Liquid and gas under pressure.
- Gas under pressure.

2. Actions necessary to protect against hazard — The following are action statements recommended by NIOSH for use on the label of a substance which presents a reactivity hazard.

- Keep from contact with oxidizing materials, highly oxygenated or halogenated solvents, organic compounds containing reducible function groups or aqueous ammonia.
- Keep from contact with oxidizing materials.
- Keep from contamination from any source including metals, dust and organic materials. Such contamination can cause rapid decomposition, generation of high pressures or formation of explosive mixtures.
- Solidifies at about _ ^{0}F (_^{0}C) and may break container. Store in moderately warm place.
- Keep from any contact with water.
- Use only dry, clean utensils in handling.
- While making solutions, add slowly to surface to avoid violent splattering.
- Keep wet in storage—dry powder may ignite by friction, static electricity or heat.
- Do not add to hot materials; do not grind or subject to frictional heat or shock—explosive decomposition may result.
- Prevent contamination with readily oxidizable materials and polymerization accelerators.
- Do not allow to evaporate to near dryness. Addition of water or appropriate reducing materials will lessen peroxide formation.
- Do not add water to contents while in a container because of violent reaction and possible flash fire.
- Do not attempt to loosen or remove material from container with any tool.
- Wear goggles and DRY gloves when handling.
- Put nothing else in this container.
- Keep dry and handle only in suitable equipment to prevent metallic contamination. Consult manufacturer.
- Keep container tightly closed and away from water or acids.
- Keep container tightly closed; flush container clean before discarding.
- Do not put in stoppered or closed container.
- Note: Suck-back into cylinder may cause explosion. Under no circumstances should the cylinder entry tube be inserted in a liquid or gas without a vacuum

break or other protective apparatus in the line to prevent suck-back.

- Store in original vented container.
- Store in cool place.
- Keep drum in upright position. Do not roll drum on side.
- Handle under inert gas atmosphere in DRY equipment.
- Keep from freezing.
- Loosen closure cautiously before opening.
- Store separately from, and avoid contact with, dehydrating materials and other materials.
- Keep away from fire.
- Open container carefully and only in dry oxygen-free or inert atmosphere.
- Store in cool dry place.
- Store in cool place in original container and protect from direct sunlight.
- Keep container closed to prevent drying out.
- Do not heat cylinders.
- Keep away from acids and heat.
- Never return unused HYDROGEN PEROXIDE to container. Dilute with plenty of water.
- Avoid spillage and contact with moisture or combustibles.
- Fire or high temperatures may cause explosive decomposition if confined.
- In case of fire, smother with dry sand, dry ground limestone or dry powder type materials specially designed for metal powder fires. Do not use carbon tetrachloride, carbon dioxide extinguishers or water.
- Do not use air pressure to transfer.

PART II – FIRST AID STATEMENTS

The following are ten first aid statements recommended by NIOSH for use on the label of a hazardous substance. Most manufacturers will provide on request appropriate first aid directions.

CALL A PHYSICIAN AS SOON AS POSSIBLE – If swallowed, induce vomiting by sticking finger down throat or by giving soapy or strong salty water to drink. Repeat until vomit is clear. Never give anything by mouth to an unconscious person.

CALL A PHYSICIAN AS SOON AS POSSIBLE – In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. (Discard contaminated shoes).

CALL A PHYSICIAN AS SOON AS POSSIBLE – If inhaled, remove to fresh air. If not breathing give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen.

CALL A PHYSICIAN AS SOON AS POSSIBLE – In case of eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Remove contact lenses if worn.

CALL A PHYSICIAN AS SOON AS POSSIBLE – In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Flush skin with water. (Wash clothing before reuse.)

In case of contact, immediately wash skin with soap and plenty of water.

Do NOT induce vomiting. Call a physician as soon as possible.

Antidote: (indicate commonly available antidote.)

Note to Physicians: (Give detailed specific treatment including drug dosage.)

Call the Life Squad or local emergency unit.

PART III – CLEANUP AND DISPOSAL INSTRUCTIONS

The following are cleanup and disposal instructions recommended by NIOSH for use on the label of a hazardous substance. For information regarding applicable local, state and federal regulations, the industrial/vocational education supervisor and instructor should contact the appropriate government bureau, including the Environmental Protection Agency.

- Flush spill area with water spray.
- Soak up spill with sand or earth. Do not use water.
- Flush away spill by flooding with water applied quickly to entire spill.
- Keep upwind of leak: Evacuate enclosed places until gas had dispersed.
- Dike spill and decomtaminate by . . .
- Do not flush into sewers.
- Dispose of sodium by burning carefully in an open fire.
- Sweep up spillage with strong calcium hypochlorite solution.
- Treat spillage with strong calcium hypochlorite solution and flush to sewer.
- In case of spillage, keep wet and remove carefully.
- Soak up with rags and dispose in covered metal containers.
- Consult local solid waste regulations for safe disposal.
- Do not sweep. Use vacuum cleaning equipment only.

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APPENDIX D

SAMPLE MATERIAL SAFETY DATA SHEET

The following Material Safety Data Sheet is recommended as part of *An Identification System for Occupationally Hazardous Materials* (U.S. Department of Health, Education, and Welfare, NIOSH, 1974).

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.
ADDRESS	
TRADE NAME	
SYNONYMS	

II HAZARDOUS INGREDIENTS

MATERIAL OR COMPONENT	%	HAZARD DATA

III PHYSICAL DATA

BOILING POINT, 760 MM HG		MELTING POINT	
SPECIFIC GRAVITY (H_2O = 1)		VAPOR PRESSURE	
VAPOR DENSITY (AIR = 1)		SOLUBILITY IN H_2O, % BY WT.	
% VOLATILES BY VOL.		EVAPORATION RATE (BUTYL ACETATE = 1)	
APPEARANCE AND ODOR			

IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	

FLAMMABLE LIMITS IN AIR, % BY VOL.	LOWER		UPPER	

EXTINGUISHING MEDIA	
SPECIAL FIRE FIGHTING PROCEDURES	
UNUSUAL FIRE AND EXPLOSION HAZARD	

V HEALTH HAZARD INFORMATION

HEALTH HAZARD DATA

ROUTES OF EXPOSURE

INHALATION

SKIN CONTACT

SKIN ABSORPTION

EYE CONTACT

INGESTION

EFFECTS OF OVEREXPOSURE

ACUTE OVEREXPOSURE

CHRONIC OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

EYES:

SKIN:

INHALATION:

INGESTION:

NOTES TO PHYSICIAN

VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

INCOMPATIBILITY

HAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

VI SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IF RELEASED OR SPILLED

NEUTRALIZING CHEMICALS

WASTE DISPOSAL METHOD

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL)

EYE

GLOVES

OTHER CLOTHING AND EQUIPMENT

IX SPECIAL PRECAUTIONS

PRECAUTIONARY STATEMENTS	
OTHER HANDLING AND STORAGE REQUIREMENTS	

PREPARED BY:

ADDRESS:

DATE:

APPENDIX E

CHEMICAL CAUSES OF SKIN MALADIES

Adapted and reprinted with permission from *Fundamentals of Industrial Hygiene,* 2nd ed. (Chicago: National Safety Council, 1979), pp. 209–215.

13-95

TABLE 17

CHEMICAL CAUSES OF SKIN MALADIES

Irritant or Agent	*Primary Irritants*	*Sensitizers*	*Manifestations of Irritating Action on the Skin (More important damages may result in other organs.)*	*Typical Occupations, Trades or Processes Where Exposure may Occur*
ACIDS				
Chromic	X X	X	Ulcers ("chrome holes") on skin, inflammation and perforation of nasal septum	Platers, manufacturing chemicals and dyestuffs
Hydrochloric	X		Irritation and ulceration of skin	Bleachers, picklers (metals), refiners (metals), tinners, chemical manufacturing
Nitric	X		Severe skin burns and ulcers	Nitric acid workers, eletroplaters, metal refiners, acid dippers, nitrators, soda makers
Oxalic	X		Local caustic action on skin, bluish discoloration and brittleness of nails	Tannery workers, blueprint paper makers, oxalic acid makers
Picric	X		Red rash (resembling that of scarlet fever), itching skin, a yellow discoloration of skin and hair which is neither a dermatitis nor a dermatosis	Explosives workers, picric acid makers, duers and dye makers, tannery workers
Sulfuric	X		Corrosive action on skin, severe inflammation of mucous membranes	Nitrators, picklers (metals), dippers, chemical manufacturing
ALKALIS				
Sodium or potassium cyanide	X		Blisters, ulcers	Electroplaters, case hardening, extraction of gold
OILS				
Cutting oils—oil emulsions or soluble oil mixtures		X	Oil acne, inflammation of hair follicles	Machinists
SALTS OR ELEMENTS				
Antimony and its compounds	X		Irritation and eczematous eruptions of skin	Antimony extractors, glass and rubber mixers, manufacturing of various alloys, fireworks, and aniline colors

TABLE 17 (Concluded)

Irritant or Agent	*Primary Irritants*	*Sensitizers*	*Manifestations of Irritating Action on the Skin (More important damages may result in other organs.)*	*Typical Occupations, Trades or Processes Where Exposure may Occur*
Arsenic and its compounds	X	X	Darkening of skin, perforation of nasal septum, epithelioma, formation of horny growth or tissue on palm, eczema around nose (possible loss of mails and hair)	Artifical leather makers carroters (felt hats), manufacturing insecticides, glass industry and vermicides, manufacturing artifical flowers, calico printing
SOLVENTS				
Acetone	X		Dry (defatted) skin	Spray painters, celluloid industry, artificial silk and leather workers, acetylene workers, lacquer and varnish makers, electrical equipment manufacturing
Benzene and its homologues (toluene and zylene	X		Dry (defatted) skin	Chemical, rubber, and artificial leather manufacturing, dry cleaning
Carbon disulfide	X	X	Dry (defatted) irritated skin	Extraction of oils, fats, and a wide range of other materials, manufacturer of rayon, rubber, and a wide range of cements, germicides, and other materials
Chlorinated phenois	X	X	Severe eruptions	Treating wood
Petroleum distillates	X	X	Acne, epithelioma	Petroleum refiners, machinists, furniture polishers
Trichloroethylene	X	X	Dry cracked skin	Degreasers, paint removers
Turpentine	X	X	Red or blistered skin, eczema	Painters, furniture polishers, lacquerers
SOAPS AND SOAP POWDERS containing an excess of free alkalis		X	Eczema, blisterlike eruptions, chronic abscesses	Soap manufacturing, dish-washers, scrubwomen, soda fountain clerks

UNIT 14

PERSONAL PROTECTIVE EQUIPMENT

METHODS	Lecture and Demonstration LENGTH: 60 Minutes
PURPOSE	To discuss the ways that personal protective equipment can reduce injuries and illnesses in the industrial/vocational education shop.
OBJECTIVES	To introduce participant to: 1. The place of personal protective equipment in the total hazard control program 2. Factors to consider in selecting personal protective equipment 3. Problems which hamper the effectiveness of personal protective equipment 4. Devices used to provide head, eye, face, hearing, respiratory, arm, hand, body, leg and foot protection 5. Care and maintenance of protective devices.
SPECIAL TERMS	1. Suspension System 2. Air-Purifying Respirator 3. Supplied—Air Respirator 4. Self-Contained Breathing Device 5. Toe Box
INSTRUCTOR MATERIALS	Lesson Plan 35 mm Slides, Projector and Screen Chalk Board/Chalk
TRAINEE MATERIALS	Participant Outlines and Supplementary Materials

UNIT 14

PERSONAL PROTECTIVE EQUIPMENT

INTRODUCTION

In Unit 3, in the discussion of the ways hazards are controlled in the industrial/vocational education shop, we learned that the last—but sometimes the only—practical way to reduce illnesses and injuries is to use personal protective equipment. In this category are included helmets, gloves, goggles, respirators, special footwear and other items which protect the student against such hazards as flying particles, noise, dangerous chemicals and electric shock.

The shortcoming of personal protective equipment is major: PPE does nothing to reduce or eliminate the hazards. For this reason such devices are normally considered the last line of defense. PPE does not take the place of such engineering controls as substitution, isolation and ventilation.

Protective equipment also creates an undue feeling of security. Its failure means immediate exposure to the hazard. Should a protective device become ineffective without the knowledge of the wearer, he is placed unwittingly in a very dangerous situation.

SELECTING PERSONAL PROTECTIVE EQUIPMENT

When a decision is made to employ protective equipment, those selecting the equipment should examine carefully six criteria.

Extent of Hazard Must be Determined

1. The extent of the hazard's potential to cause harm must be evaluated. It is important to have a clear understanding of the nature of the hazard, where it originates, what harm it can cause and the likelihood of its occurrence. For example, if a respirator is needed to protect students from dust, the size of the dust particles must be determined. Without such a determination, a respirator could be selected which may not perform its desired function.

Degree of Protection is in Proportion to Seriousness of Hazard

2. The degree of desired protection is in direct proportion to the seriousness of the hazard. Two dangers are present in selecting PPE: the danger of "overkill" and the danger of selecting equipment which offers inadequate protection. For example, greater face protection is required to guard

against chemical splashes than is necessary for protection against the impact of flying objects. To offer the same device for both would mean either overprotection or underprotection, depending on which alternative is selected.

Interference Must be Balanced Against Protection

3. Protection must be considered along with the equipment's ability to interfere with the student's performance in the shop. Bulky gloves may decrease the dexterity required for certain tasks; full face shields may be cumbersome during certain operations. Sometimes those selecting protective equipment must weigh the benefits of the most desirable alternative against the most practical one before making the final selection.

Equipment Should Carry ANSI Label

4. For most protective equipment (head, eye, face and foot protection, electrical protective devices), a label showing compliance with the appropriate American National Standards Institute (ANSI) standard will be affixed to the product. In the case of respiratory equipment, the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) have their label attached to the product. There are some types of protective equipment—for example, gloves and aprons—for which no approvals are available.

Quality Pays for Itself

5. Quality is an important factor to be considered at the time of purchasing protective equipment. Although many manufacturers are selling equipment which meets the ANSI standards and NIOSH and MSHA approvals, their products are not all of the same quality. Given the constraint of cost, equipment of the highest quality should be purchased for use in the industrial/vocational education shop. A product of high quality will be easier to maintain and can be expected to have a longer service life than less expensive equipment.

Cost Should be Weighed Against Service Life

6. Last but not least is the cost of the equipment. Good protective equipment is not inexpensive. The highest quality equipment on the market normally costs proportionally more than its lower quality counterpart. When a decision must be made to determine how much will be spent on protective equipment, it is important to determine how long the equipment will be needed. If it will be used only for a short period of time while more suitable

control measures are being installed, less expensive equipment may serve the purpose. However, if the protective equipment is intended to serve its purpose indefinitely, then strong consideration should be given to allocating ample funds to acquire the highest quality approved products.

PROBLEMS INTERFERING WITH EFFECTIVENESS OF PPE

When the foregoing criteria have been evaluated, the job of the purchaser is still far from over. Now he must concern himself with solving problems which interfere with the effectiveness of PPE.

Purchasing More than One Type of Same Class

When more than one variety of the same class of protective device is employed in the shop (for example, more than one brand of respirator), especially if each type has slightly different requirements for use, care and maintenance, it becomes difficult for instructors and supervisors to train students in the use of the equipment and to provide adequate maintenance, monitoring and control. Ideally one brand of a particular class of protective equipment should be used throughout the school.

Insufficient or Improper Equipment Maintenance

If protective equipment is to continue providing protection, it requires care and maintenance. A program of student care and school maintenance must be developed and must be in operation at the time when the equipment is distributed for use. Cleaning and minor repairs are usually done in the shop or by the school's maintenance organization. More complex repairs or repairs designated to be done by the manufacturer should not be made by school personnel. In such instances the equipment should be returned to the manufacturer or his designated service representative.

Improper Fit

Improperly fitted protective equipment discourages student acceptance and in some cases causes a loss of protection. For instance, protective eye wear which does not fit properly may end up in the student's pocket, and a respirator facepiece which does not seal properly on a student's face will allow the toxic substance to enter the facepiece and be inhaled by the student. When purchasing protective equipment, consideration should be given to the need for proper fit. In cases where a student or instructor cannot acquire a proper fit with conventional equipment, special fitting devices may be necessary.

Insufficient Training and Education

Unless the persons who are required to wear the equipment are trained and educated in its necessity, its proper use and its care and maintenance, protective equipment will do little to fulfill its intended purpose. Every supervisor and instructor needs to stress use, care and maintenance as an integral part of overall shop operations.

HEAD PROTECTION

Head protection can be divided into three categories:

1. caps for long hair
2. bump caps
3. helmets or safety hats.

Caps for Long Hair

Protective hair covering is necessary for students with long hair who work at machines. Besides the obvious danger of hair becoming entangled in moving parts when the student bends over, there is also the possibility that heavy charges of static electricity can lift hair into moving belts or rolls.

Protective caps should cover the hair completely. Bandanas and turbans are not sufficient and pose their own hazards if they become loose. Although no standards have been accepted, protective fabric caps should be made of a durable, flame-proof fabric rugged enough to withstand regular laundering. The cap should have a visor long enough and rigid enough to provide warning before the head itself comes into contact with a moving object, such as the spindle on a drill press.

Bump Caps

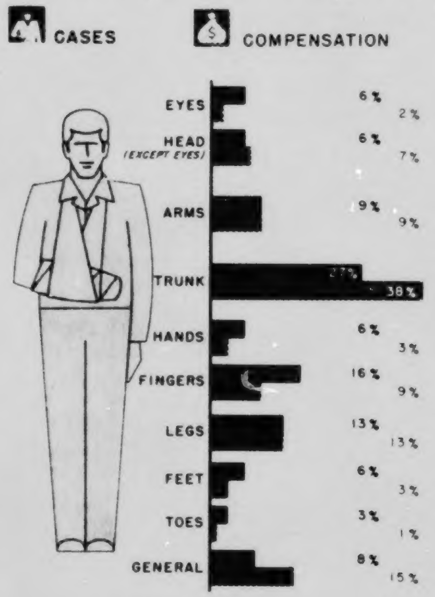
Bump caps are thin-shelled, lightweight plastic headgear. They are not a substitute for helmets and do not provide the kind of protection needed in the industrial/vocational education shop.

Helmets (Hard Hats)

Helmets, also called safety or hard hats, are the best means for protecting students and instructors alike against impact blows and penetration from flying and falling objects and from limited electric shock. They can be designed to protect the scalp, face and neck from overhead spills, can keep hair from entanglement in machinery and can shield the scalp from exposure to irritating dusts.

The National Safety Council estimates that approximately 140,000 head injuries occur in a given year (see Figure 36). These injuries are caused by workers being struck by or against objects or from falls. Many of the same situations responsible for causing head injuries in industry are present in the industrial/vocational education shop.

Part of body injured in work accidents



Source: State Labor Departments, 1972-1973,
cases — 19 States, compensation — 9 States

In one recent year disabling work injuries in the entire nation totalled approximately 2,300,000. Of these, about 13,000 were fatal and 80,000 resulted in some permanent impairment.

Injuries to the trunk occurred most frequently, with thumb and finger injuries next, according to State Labor Department reports.

Eyes	140,000
Head (except eyes)	140,000
Arms	210,000
Trunk	610,000
Hands	140,000
Fingers	370,000
Legs	300,000
Feet	140,000
Toes	70,000
General	180,000

For each body part the chart on the left shows (on top) the percent of all injuries, (on the bottom) the percent of all compensation paid.

Adapted and reprinted with permission from *Accident Facts* 1978 (Chicago: National Safety Council, 1978), p. 26.

Figure 36

Helmets are of two types, either full brimmed or brimless with peak. A brim provides the most complete protection for head, face and back of neck. The cap type is used where a brim may be in the way.

Classes of Hard Hats

There are four classes of hard hats:

1. Class A, affording limited voltage resistance, for general service
2. Class B, high voltage resistance
3. Class C, no voltage protection (metallic helmets)
4. Class D, limited voltage protection, fire fighters' service only.

All helmets must meet the requirements and specifications in the American National Standards Institute Z89.1, Safety Requirements for Industrial Head Protection. Helmets are identified on the inside of the shell with the manufacturer's name, and ANSI designation and the class.

Helmets (hard hats) are designed to transmit a maximum average force of not more than 850 pounds (385 kilograms) when tested in accordance with ANSI Z89.1. Hard hats which meet ANSI standards are designed with two major components, a shell and a suspension:

Shell

- The *shell* should be of one piece, seamless construction and designed to resist impact.

Suspension

- The *suspension* gives the hard hat its impact-distributing abilities. The suspension must be adjusted to fit the wearer, and a clearance of not less than 1-1/4" (3.18 cm.) must be maintained between the shell and the skull of the wearer.

Chinstrap, Nape Strap

A chinstrap will keep a hat from coming off. It affords full protection. A nape strap, provided with most helmets, helps to keep the headgear from falling off during normal use. Some headgear comes with removable type attachments for face shields, welding helmets and so forth.

Care of Hard Hats

To care for and maintain helmets effectively, the following recommendations should be followed:

Inspect Hard Hats

1. Before each use, hard hats should be inspected for cracks and signs of impact. Once damaged, a protective helmet should be discarded. Alterations of any kind weaken the performance of the helmet.

Inspect Suspensions

2. Suspension systems should be inspected frequently to detect loose or torn cradle straps, broken sewing lines, loose rivets, defective lugs, etc. Once found, deteriorated systems should be replaced.

Remove Agents from Shell

3. Chemicals, oils and petroleum products must be removed from the shell as soon as possible. These agents will soften the shell materials and reduce its impact and dielectric protection. The manufacturer should be consulted as to what solvents can be used to remove such chemicals without themselves causing damage. If a hard hat needs painting, the manufacturer should be consulted so that a coating can be selected which will not harm the helmet.

Clean Hard Hats Regularly

4. Hard hats must be scrubbed and disinfected before being reissued to others. At least every thirty days the hat, sweat bands and cradles should be washed in warm soapy water or an approved detergent solution recommended by the manufacturer. Thorough rinsing should follow washing.

5. While in storage, hard hats should not be exposed to bright sunlight. Heat and light may reduce the degree of protection that they provide.

EYE PROTECTION

The protection of eyes from damage by physical and chemical agents long has been an important part of a hazard control program. Some 140,000 disabling injuries occur annually, injuries that result in total or partial blindness.

In the industrial/vocational education shop the eyes are exposed to a variety of hazards: flying objects, splashes of corrosive liquids or molten metals, dust and harmful radiation. OSHA requires that eye and face protection be designed to meet the performance requirements set forth in ANSI Z87.1, Practice for Occupational and Educational Eye and Face Protection.

Selecting Eye Protective Equipment

Before selection is made, consideration must be given to:

- the extent of the hazard to be guarded against
- the ability of the eye-protective materials to afford this protection
- the type of eye protection devices that fit the work objective.

Figure 37 illustrates recommended eye and face protectors for use in industry, schools and colleges, and indicates which type is recommended for particular operations.

Protection Against Flying Particles

Conditions requiring protection from flying particles caused by chipping, drilling, grinding and so forth require the selection of one of three types of impact-protection equipment.

1. spectacles with impact-resistant lenses
2. flexible or cushion-fitting goggles
3. chipping goggles.

Spectacles with Impact-Resistant Lenses

Spectacles without side shields are not recommended because of the limited protection they provide. Normally side as well as frontal protection is required. Full-cup side shields restrict flying particles from entering the wearer's eyes from the side. Semi- or fold-flat side shields may be used where only lateral protection is required.

Flexible and Cushion-Fitting Goggles

Both flexible and cushion goggles usually have a single lens. These goggles give both frontal and side protection from flying particles.

Chipping Goggles

Chipping goggles give maximum protection from flying particles. They come in two styles, either for use without other eyewear or for fitting over corrective lenses. Both types have coutour-shaped rigid plastic eyecups.

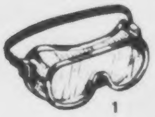
Protection Against Fumes and Liquids

Students exposed to chemical fumes and liquids on such jobs as handling volatile and corrosive chemicals, dipping in plating and pickling tanks, and so forth require chemical splash goggles or a face shield for adequate protection.

Chemical goggles have soft vinyl or rubber frames and lenses made

Selection Chart for Eye and Face Protectors for Use in Industry, Schools, and Colleges

This Selection Chart offers general recommendations only. Final selection of eye and face protective devices is the responsibility of management and safety specialists. (For laser protection, refer to American National Standard for Safe Use of Lasers, ANSI Z136.1-1976.)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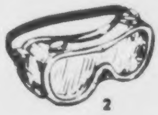
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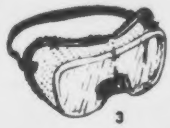
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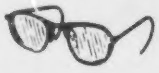
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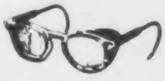
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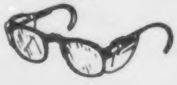
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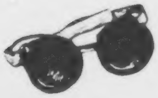
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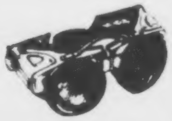
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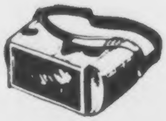
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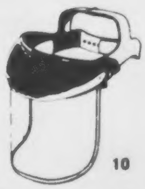
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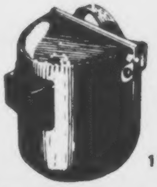
11

1. GOGGLES, Flexible Fitting, Regular Ventilation
2. GOGGLES, Flexible Fitting, Hooded Ventilation
3. GOGGLES, Cushioned Fitting, Rigid Body

*4. SPECTACLES, without Sideshields
5. SPECTACLES, Eyecup Type Sideshields
6. SPECTACLES, Semi-/Flat-Fold Sideshields

**7. WELDING GOGGLES, Eyecup Type, Tinted Lenses (Illustrated)

7A. CHIPPING GOGGLES, Eyecup Type, Clear Safety Lenses (Not Illustrated)

**8. WELDING GOGGLES, Coverspec Type, Tinted Lenses (Illustrated)

8A. CHIPPING GOGGLES, Coverspec Type, Clear Safety Lenses (Not Illustrated)

**9. WELDING GOGGLES, Coverspec Type, Tinted Plate Lens

10. FACE SHIELD, Plastic or Mesh Window (see caution note)

* 11. WELDING HELMET

*Non-sideshield spectacles are available for limited hazard use requiring only frontal protection.

**See Table A1, "Selection of Shade Numbers for Welding Filters," in Section A2 of the Appendix.

APPLICATIONS

OPERATION	HAZARDS	PROTECTORS
ACETYLENE–BURNING ACETYLENE–CUTTING ACETYLENE–WELDING	SPARKS, HARMFUL RAYS, MOLTEN METAL, FLYING PARTICLES	7, 8, 9
CHEMICAL HANDLING	SPLASH, ACID BURNS, FUMES	2 (For severe exposure add 10)
CHIPPING	FLYING PARTICLES	1, 3, 4, 5, 6, 7A, 8A
ELECTRIC (ARC) WELDING	SPARKS, INTENSE RAYS, MOLTEN METAL	11 (In combination with 4, 5, 6, in tinted lenses, advisable)
FURNACE OPERATIONS	GLARE, HEAT, MOLTEN METAL	7, 8, 9 (For severe exposure add 10)
GRINDING–LIGHT	FLYING PARTICLES	1, 3, 5, 6 (For severe exposure add 10)
GRINDING–HEAVY	FLYING PARTICLES	1, 3, 7A, 8A (For severe exposure add 10)
LABORATORY	CHEMICAL SPLASH, GLASS BREAKAGE	2 (10 when in combination with 5, 6)
MACHINING	FLYING PARTICLES	1, 3, 5, 6 (For severe exposure add 10)
MOLTEN METALS	HEAT, GLARE, SPARKS, SPLASH	7, 8 (10 in combination with 5, 6, in tinted lenses)
SPOT WELDING	FLYING PARTICLES, SPARKS	1, 3, 4, 5, 6 (Tinted lenses advisable; for severe exposure add 10)

CAUTION:

- Face shields alone do not provide adequate protection.
- Plastic lenses are advised for protection against molten metal splash.
- Contact lenses, of themselves, do not provide eye protection in the industrial sense and shall not be worn in a hazardous environment without appropriate covering safety eyewear.

Figure 37

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of heat-treated glass or acid-resistance plastic. For exposures involving chemical splashes, the goggles are equipped with baffled ventilators on the side.

Protection Against Hot Splashing Metals

Where students may come into contact with hot splashing metals (in casting, tinning, pouring lead joints and so forth), cup goggles with impact-resistant lenses, metal screen face shields or heavy plastic shields with impact-resistant spectacles beneath are required.

Protection Against Light Rays

Injurious rays are encountered in torch brazing, gas welding and cutting, arc welding and so forth. Eye protection for welding operations should be chosen carefully to cope with the particular hazard as well as chemical and physical agents.

To exclude injurious flashes, hot metal and sparks and to save the welding lenses from pitting, the student who is flame welding, brazing or cutting should wear goggles with impact-resistant filter lenses. The goggles may have clear or colored glass depending upon the amount of exposure from adjacent welding operations.

According to federal statute, goggles or other suitable eye protection must be used during all gas welding or oxygen cutting operations. Spectacles with suitable filter lenses are permitted during gas welding operations on light work, for torch brazing or for inspection.

For electric arc welding involving exposure to ultraviolet rays, it is important that the filter lenses protect the student from the ultraviolet rays as well as from the glare. Table 18 illustrates the proper shade number for eye protection in various welding operations.

Requirements for Eye Protectors

Protectors must meet the following minimum requirements mandated in OSHA Safety and Health Standards (29 CFR 1910.133):

1. They must provide adequate protection against the particular hazards for which they are designed.

2. They must be reasonably comfortable when worn under the designated conditions.

3. They must fit snugly and must not interfere unduly with the movements of the wearer. Instructors should be trained in the fitting of goggles to assure proper fit.

TABLE 18

FILTER LENS SHADE NUMBER FOR EYE PROTECTION

Welding Operation	Shade Number
Shielded metal-arc welding 1/16-, 3/32-, 5/32-inch diameter elctrodes	10
Gas-shielded arc welding (nonferrous) 1/16-, 3/32-, 1/8-, 5/32-inch diameter electrodes	11
Gas-shielded arc welding (ferrous) 1/16-, 3/32-, 1/8-, 5/32-inch diameter electrodes	12
Shielded metal-arc welding 3/16-, 7/32-, 1/4-inch electrodes	12
5/16-, 3/8-inch diameter electrodes	14
Atmoic hydrogen welding	10-14
Carbon-arc welding	14
Soldering	2
Torch brazing	3 or 4
Light cutting, up to 1 inch	3 or 4
Medium cutting, 1 inch to 6 inches	4 or 5
Heavy cutting, over 6 inches	5 or 6
Gas welding (light), up to 1/8-inch	4 or 5
Gas welding (medium), 1/8 inche to 1/2 inch	5 or 6
Gas welding (heavy), over 1/2-inch	6 or 8

Reprinted from General Industry OSHA Safety and Health Standards (29 CFR 1910.252e), U.S. Department of Labor, November 1978, p. 448.

4. They must be durable.
5. They must be capable of being disinfected. However, it is important that sterilizing solutions be removed so that skin irritation will not result.
6. They must be easily cleaned.

Under conditions where goggles are apt to fog up, care must be given to the selection of eye wear with ventilation. In extreme cases, antifog compounds should be used inside lenses.

Corrective Lenses

According to OSHA regulations, students wearing corrective lenses must wear one of the following:

1. spectacles with protective lenses which provide optical correction

2. goggles that can be worn over corrective spectacles without disturbing the adjustment of the spectacles

3. goggles which incorporate corrective lenses mounted behind the protective lenses.

Prescription eyeglasses or contact lenses worn in eye hazard areas require approved eye protection.

Contact Lenses

Both the National Society for the Prevention of Blindness and the American Optometric Association advise the use of contact lenses in industry only in conjunction with proper safety shields, goggles or other protection. Two special precautions apply to wearers of contact lenses:

1. If caustic, chemical or other solutions are accidentally splashed in the eye, the cornea may be burned. In the event of such an accident, first flush out the eye, then remove the lens, then flush the eye again.
2. If a foreign body (dust, for example) gets under a contact lens, it may scratch the cornea. In the event of such an accident, remove the lens immediately. It may be necessary to consult a physician to make sure the foreign body is no longer present.

FACE PROTECTION

Several types of PPE shield the face (and sometimes the head and neck as well) from flying particles, chemical or hot metal splashes and heat radiation. These include:

Clear Plastic Face Shields

1. face shields of clear plastic, to protect the eyes and face of a person who is sawing or buffing metal, sanding or light grinding or handling chemicals

Face Shields with Metal Screens

2. face shields with metal screens, to deflect heat from a person working near furnaces

Babbitting Helmets

3. babbitting helmets consisting of

    a. a window made of extremely fine wire screen

b. a tilting support

c. an adjustable headgear

d. a crown protector and used to protect the head and face against splashes of hot metal.

Welding Helmets, Shields and Goggles

4. welding helmets, shields and goggles, to protect the eyes and face against both the splashes of molten metal and the radiation produced by arc welding

Acid-Proof Hoods

5. acid-proof hoods, with a window of glass or plastic, to protect the head, face and neck of persons exposed to possible splashes from corrosive chemicals

Air-Supplied Hoods

6. air-supplied hoods, for work around toxic fumes, dusts, gases or mists. These will be discussed when we examine respiratory protection devices.

As a general rule, face shields should be worn over suitable eye protection.

HEARING PROTECTION EQUIPMENT

The need for personal hearing protection arises when source control and/or path control are not present, when source and/or path control do not lower noises to safe levels or when a person in the industrial/vocational education shop cannot avoid direct exposure to noisy equipment and tools. There are three basic types of personal hearing protection devices.

Pliable Insert Material

1. Disposable pliable material, such as fine glass wool, mineral fibers and wax-impregnated cotton, may be inserted in the ear. It must be fresh each day.

Ear Plugs

2. Ear plugs may be inserted into the ear. They must be individually fitted to the wearer.

Cup-Type Protectors

3. Cup-type protectors—like ear muffs—may be worn with the band over the head or around the back of the neck or may be incorporated into safety helmets.

Selecting Hearing Protective Devices

To a great extent, selection of a protective device is governed by individual preference. Factors to consider are effectiveness, comfort (which is often a problem) and cost.

While cotton alone is a poor choice, when paraffin wax is mixed into the cotton the material becomes much more efficient. Glass down, also called "Swedish wool," is another pliable material. Rubber and plastic types are popular because they are inexpensive, easy to clean and give good performance. Wax tends to lose its effectiveness because jaw movement (talking, chewing or yawning) changes the shape of the ear canal; this breaks the acoustic seal between ear and insert.

25–30 dB

Ear plugs specially molded to the individual's ear canal offer excellent protection, generally reducing the noise reaching the ear by 25 to 30 decibels. However, they must be fitted by a trained, qualified person, and they should become the property of the individual for whom they are molded.

Neither of these types should cause skin irritation or injured ear drums if they are properly designed, well fitted and hygienically maintained.

Additional 10–15 dB

Cup- or muff-type devices cover the external ear to provide an acoustic barrier. They can reduce noise an additional ten to fifteen decibels. Their effectiveness if influenced by size, shape, seal material, shell mass and type of suspension, as well as by individual head size and shape. Glasses or long hair can break the seal over the ear.

Additional 3–5 dB

Combinations of ear plugs and ear muffs give three to five more decibels of protection.

Cup-type protectors cost more than other devices. However, this is a one-time cost; over a period of time, the cost of pliable insert material will exceed the cost of the cup-type protector.

Under dusty or dirty working conditions, cup-type protectors may be more hygienic than devices inserted in the ear. Under hot working conditions, pliable insert material or ear plugs may be more comfortable than cup-type devices.

It is imperative that anyone exposed to potentially dangerous noise levels have some kind of hearing protection.

RESPIRATORY PROTECTION

During our discussion of health hazards in the previous unit, we examined the three modes of entry for hazardous materials: ingestion, skin absorption and inhalation. We saw that the human respiratory system presents the quickest and most direct avenue of entry because it is intimately and inextricably connected with the circulatory system and the need to oxygenate tissue cells to sustain life processes.

When Respirators are Needed

The Occupational Safety and Health Administration (OSHA) and states working under an approved OSHA State Plan have established permissible exposure limits (PELs) for many airborne toxic materials. OSHA Standards (29 CFR 1910.134) state:

> In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used.

Respiratory protection is also required on several special occasions:

1. in oxygen-deficient atmospheres where the oxygen content in the breathable air is insufficient
2. for routine but infrequent operations
3. for non-routine operations in which persons are exposed briefly to high concentrations of a hazardous substance during maintenance, repair or emergency conditions.

Identifying and Evaluating Hazards

Those conducting a health hazard assessment will concentrate on locating four major categories of respiratory hazards:

1. oxygen-deficient atmospheres
2. gas and vapor contaminants
3. particulate contaminants (including dust, fog, fume, mist, smoke and spray)
4. combinations of gas, vapor and particulate contaminants.

It is important to determine what type or types of contaminants exist in the industrial/vocational education shop in order to select intelligently the most effective respiratory equipment. Because each respirator is designed to provide protection for a certain contaminant or group of contaminants, an arbitrary choice on the part of school administrators could place their personnel and students in a dangerous situation.

Before a respirator is selected, the following questions should be asked:

1. What is the estimated contaminant concentration where the respirator will be used?
2. What is the permissible exposure limit (PEL) to the contaminant?
3. Is the contaminant a gas, vapor, mist, dust or fume?
4. Could the contaminant concentration be termed immediately hazardous to life or health?
5. If the contaminant is flammable, does the estimated concentration approach the lower explosive limit?
6. Does the contaminant have adequate warning properties?
7. Will the contaminant irritate the eyes at the estimated concentration?
8. If the contaminant is a gas or vapor, is there an available sorbent that traps it efficiently?
9. Can the contaminant be absorbed through the skin as a vapor or liquid? If so, will it cause serious injury?[1]

Selecting Respirators

The person given the responsibility for selecting respirators for the industrial/vocational education shop will be guided by ANSI Z88.2, American National Standard Practices for Respiratory Protection. Of particular importance is the MSHA/NIOSH approval on the respirator (see Figure 38).

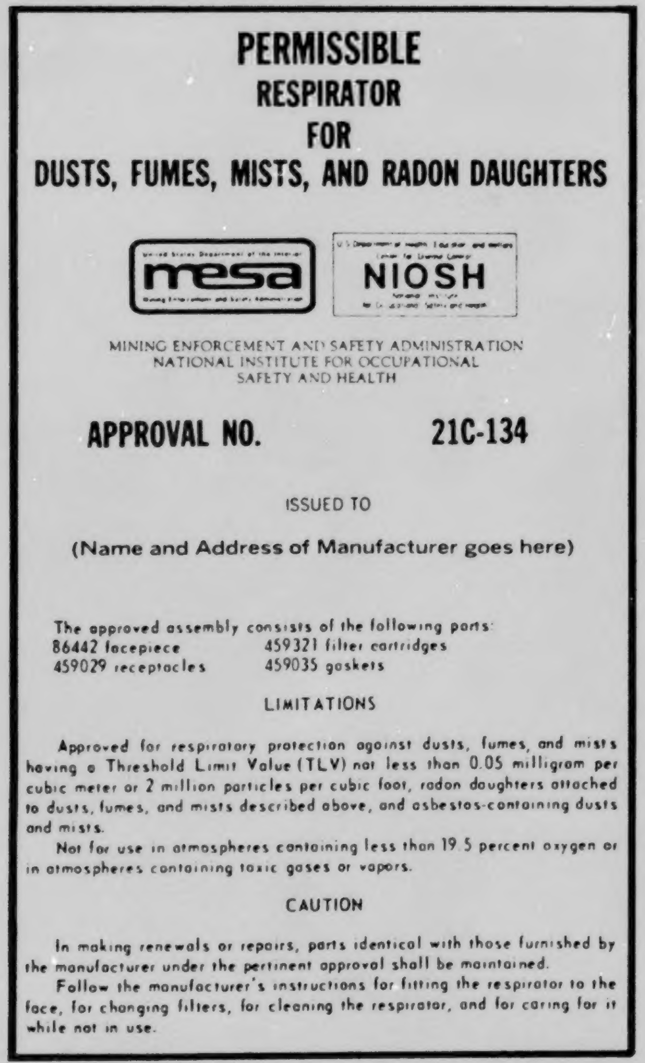
Selection should be based on:

1. the nature of the hazardous process or operation
2. the type of respiratory hazard
    a. physical and chemical properties

b. warning properties

c. physiological and psychological effects on the body

d. concentration of the material



PERMISSIBLE
RESPIRATOR
FOR
DUSTS, FUMES, MISTS, AND RADON DAUGHTERS

mesa NIOSH

MINING ENFORCEMENT AND SAFETY ADMINISTRATION
NATIONAL INSTITUTE FOR OCCUPATIONAL
SAFETY AND HEALTH

APPROVAL NO. 21C-134

ISSUED TO

(Name and Address of Manufacturer goes here)

The approved assembly consists of the following parts:

86442 facepiece	459321 filter cartridges
459029 receptacles	459035 gaskets

LIMITATIONS

Approved for respiratory protection against dusts, fumes, and mists having a Threshold Limit Value (TLV) not less than 0.05 milligram per cubic meter or 2 million particles per cubic foot, radon daughters attached to dusts, fumes, and mists described above, and asbestos-containing dusts and mists.

Not for use in atmospheres containing less than 19.5 percent oxygen or in atmospheres containing toxic gases or vapors.

CAUTION

In making renewals or repairs, parts identical with those furnished by the manufacturer under the pertinent approval shall be maintained.

Follow the manufacturer's instructions for fitting the respirator to the face, for changing filters, for cleaning the respirator, and for caring for it while not in use.

Shown here is the typical approval label which appears on a MESA/NIOSH approved respiratory protection device. The user should make certain that he understands the limitations of the device. MESA is now called MSHA, the Mine Safety and Health Administration.

Reprinted with permission of Mine Safety Appliances Company.

Figure 38

3. the period of time for which respiratory protection must be provided
4. the location of the hazard area in relation to the nearest source of uncontaminated respirable air
5. the function and physical characteristics of respiratory protective devices.[2]

Table 19 outlines a procedure for selecting respiratory protective devices.

Classes of Respirators

The three major classes of respirators are:

1. air-purifying respirators
2. supplied-air respirators
3. self-contained breathing devices.

The appendix to this unit examines the characteristics, advantages, limitations and subcategories of each of these classes. It also details the procedures for cleaning, disinfecting, storing and inspecting respirators.

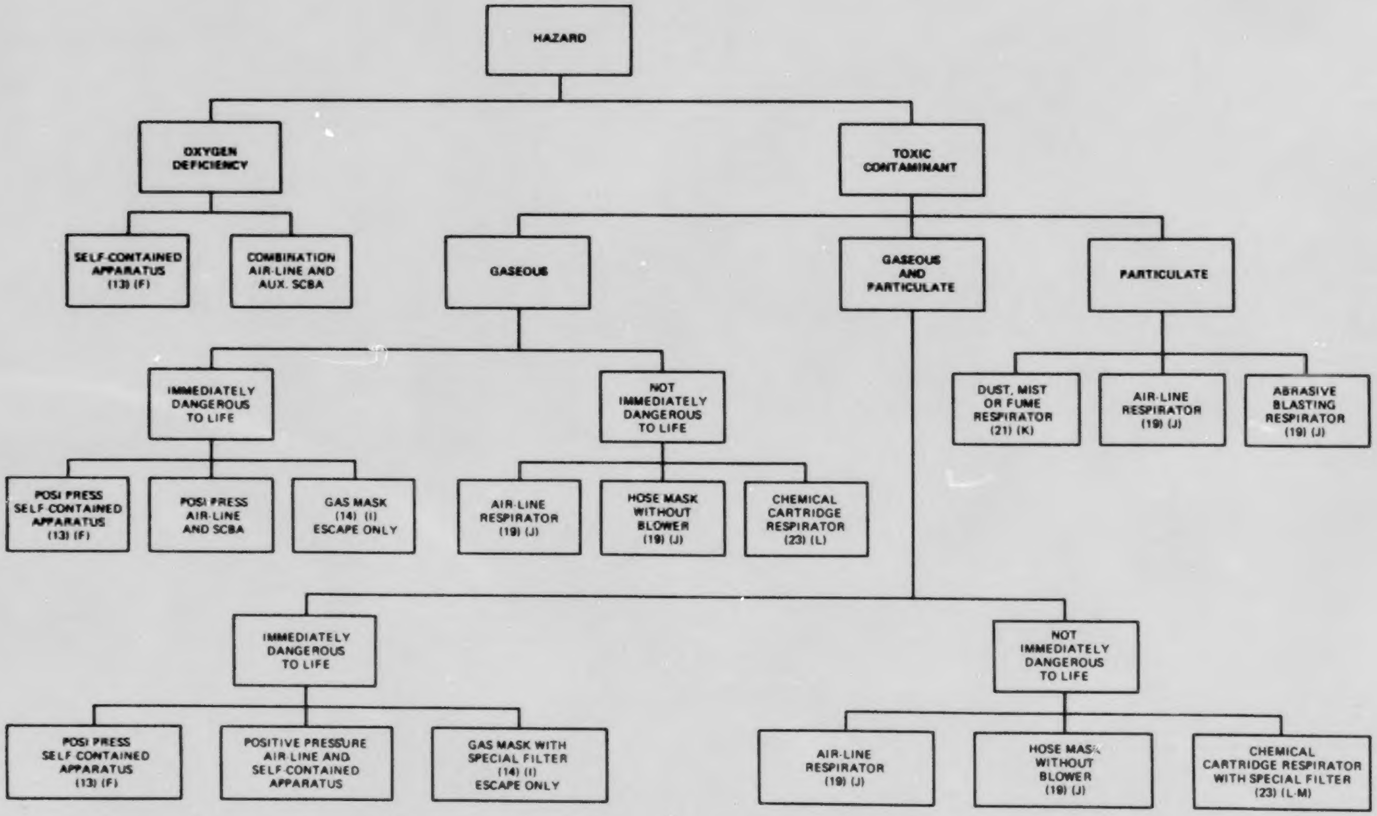
FITTING THE RESPIRATOR TO THE WEARER

It is essential that respiratory protective equipment be properly fitted to the user. All the care that went into the design and manufacture of a respirator to maximize protection will be lost if there is an improper match between facepiece and wearer. Fitting tests should be repeated at appropriate intervals, particularly when there is a change in the wearer's physical state, such as growth of facial hair or change in face contours.

Facial Hair

Facial hair lying between the sealing surface of a respirator facepiece and the wearer's skin will prevent satisfactory sealing. The sealing problem is especially critical when non-powered air-purifying respirators are used. The negative pressure developed in the facepiece of these respirators during inhalation can lead to leakage of contaminant into the facepiece when there is a poor seal. Some supplied-air respirators of the air line type, because of their mode of operation, also can lead to leakage at the sealing surface. Therefore, individuals who have stubble (even a few day's growth), a moustache, sideburns or a beard that passes between the skin and the sealing surface should not wear a respirator.

Table 19


HAZARD
OXYGEN DEFICIENCY
TOXIC CONTAMINANT
SELF-CONTAINED APPARATUS (13) (F)
COMBINATION AIR-LINE AND AUX. SCBA
GASEOUS
GASEOUS AND PARTICULATE
PARTICULATE
IMMEDIATELY DANGEROUS TO LIFE
NOT IMMEDIATELY DANGEROUS TO LIFE
DUST, MIST OR FUME RESPIRATOR (21) (K)
AIR-LINE RESPIRATOR (19) (J)
ABRASIVE BLASTING RESPIRATOR (19) (J)
POSI PRESS SELF-CONTAINED APPARATUS (13) (F)
POSI PRESS AIR-LINE AND SCBA
GAS MASK (14) (I) ESCAPE ONLY
AIR-LINE RESPIRATOR (19) (J)
HOSE MASK WITHOUT BLOWER (19) (J)
CHEMICAL CARTRIDGE RESPIRATOR (23) (L)
IMMEDIATELY DANGEROUS TO LIFE
NOT IMMEDIATELY DANGEROUS TO LIFE
POSI PRESS SELF CONTAINED APPARATUS (13) (F)
POSITIVE PRESSURE AIR-LINE AND SELF-CONTAINED APPARATUS
GAS MASK WITH SPECIAL FILTER (14) (I) ESCAPE ONLY
AIR-LINE RESPIRATOR (19) (J)
HOSE MASK WITHOUT BLOWER (19) (J)
CHEMICAL CARTRIDGE RESPIRATOR WITH SPECIAL FILTER (23) (L-M)

Based on Bureau of Mines Information Circular 7792. Numbers in parentheses refer to Bureau of Mines Schedules; letters in parentheses refer to Subpart of NIOSH/MESA 30 CFR Part 11.

Reprinted with permission from *Fundamentals of Industrial Hygiene,* 2nd ed. (Chicago, National Safety Council, 1979), p. 715.

Corrective Lenses

Corrective lenses that have temple bars or straps should not be used when a full-facepiece respirator is worn since the bars or straps could pass through the facepiece-to-face seal. Manufacturers of respiratory equipment can provide kits for installing eyeglasses in their respiratory facepieces. These glasses or lenses must be mounted by a qualified individual to ensure proper fit.

Contact Lenses

According to OSHA regulations (29 CFR 1910.134), the "wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed." A properly fitted respirator (primarily a full-facepiece respirator) may stretch the skin around the eyes, thus increasing the possibility that the contact lens will fall out. Furthermore, contaminants that do penetrate the respirator may go underneath the contact lens and cause severe discomfort. The user's first reaction—to remove the facepiece to remedy the situation—could be fatal in a lethal environment.

Miscellaneous Sealing Problems

Scars, hollow temples, very prominent cheekbones, deep skin creases and lack of teeth or dentures may cause respiratory facepiece sealing problems. Dentures or missing teeth may cause problems when sealing a mouthpiece in a person's mouth. Full dentures should be retained when wearing a respirator, but partial dentures may or may not have to be removed, depending upon the possibility of swallowing them. With full lower dentures, problems in fitting quarter-masks can be expected, as the lower part of the mask tends to unseat the denture.

TRAINING AND EDUCATION IN THE RESPIRATOR PROGRAM

Selecting the respirator appropriate to a given hazard is important, but equally important is its proper use. To ensure proper use and maintenance of respirators, a training program is needed for supervisors and students alike.

The content of the training program can vary widely, depending upon circumstances. However, OSHA 1910.134 requires that training programs for both users and supervisors include the following, regardless of circumstances:

- an opportunity to handle the respirator
- proper fitting
- test of facepiece-to-face-seal
- a long familiarizing period of wear in normal air.

Furthermore, OSHA requires that the wearer receive fitting instructions, including demonstrations and practice in wearing, adjusting and determining the fit of the respirator. These requirements originated in ANSI Z88.2.

Training of instructors and students also should include:

- discussion of the engineering and administrative controls in use and the need for respirators
- explanation of the nature of the respiratory hazard and the consequences of improper use
- explanation of respirator selection criteria
- discussion of how to recognize and handle emergencies.

ARM AND HAND PROTECTION

Statistics indicate that injuries to the arms, hands and fingers account for more than a quarter of all disabling industrial mishaps. The hazards in the industrial/vocational education shop are similar to those encountered in industry: molten metal, heat, sharp objects, chemical and corrosives, etc.

Relationship of Hand Protection to Hazard Control

Most of the more than 720,000 hand injuries which occur each year are the result of accidents suffered when operating machinery, using tools or handling materials. Personal protective equipment can do little to prevent accidents in the first of these areas. If protective gloves were worn to shield the hands from cuts and slivers when operating drills, lathes and other machine tools, the gloves themselves would become a hazard. They could snag in the revolving parts and pull the hand into the machinery. Other means must be found for protecting the hands of machine operators; guarding devices and safe, correct work procedures are the best lines of defense.

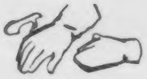
Gloves, mitts and hand pads supplement good work practices to prevent hand injuries during the handling of materials and the using of tools. There is a glove suitable for protection against many hazards that can be named: abrasions, cuts, slivers, pinch points, oils, chemicals, radiation, electricity, cold, heat and flames. Table 20 offers a convenient summary.

Types of Materials

Especially suitable to the industrial/vocational education shop are:

1. *metal mesh gloves*, to protect against cuts and blows from sharp or rough objects and tools

Table 20



TYPE OF HAND PROTECTION	CUTS, ABRASIONS	LIGHT MATERIALS HANDLING	HEAVY MATERIALS HANDLING	PINCH POINTS	CHEMICALS*	ELECTRICITY	TEMPERATURE EXTREMES	LIQUIDS*	FLAME	RADIATION**	SANITATION
KNIT COTTON (Wrist length or Gauntlet)	✓	✓					✓				
LEATHER GLOVES, HAND PADS	✓	✓	✓				✓		✓		
ASBESTOS OR ALUMINIZED GLOVES, MITTENS, PADS							✓		✓		
VARIOUS PLASTICS (Job-Rated)	✓	✓			✓			✓			✓
RUBBER – NATURAL OR SYNTHETIC (Job-Rated)	✓	✓			✓			✓		✓	✓
DISPOSABLE PLASTIC (Job Rated)		✓			✓			✓			✓
PLASTIC COATED GLASS FIBER COMBINATION		✓			✓		✓	✓			
ELECTRICAL LINEMAN'S GLOVE (Must be worn with protective leather glove)						✓					
LEATHER WITH REINFORCED METAL PALM	✓	✓	✓				✓		✓		
MAIL OR WOVEN METAL GLOVES	✓	✓									
CUFF, FOREARM GUARDS (Fiber, metal, mesh, etc.)	✓	✓	✓	✓							✓
THUMB GUARDS, FINGER COTS, PROTECTIVE WRAPPING TAPES	✓	✓		✓							
PROTECTIVE BARRIERS	✓										✓

TYPE OF HAZARD

* VARIOUS PLASTIC, RUBBER, AND DISPOSABLE RUBBER GLOVES MUST BE JOB RATED FOR WORKING WITH SPECIFIC ALKALIS, SALTS, ACIDS, OILS, GREASES, AND SOLVENTS

** FOR NUCLEAR RADIATION HAZARDS AND X RAYS, THERE ARE AVAILABLE LEADED RUBBER, LEADED PLASTIC, AND LEADED LEATHER APPAREL

Reprinted with permission from "Work Gloves" *National Safety News* (July 1978), p. 78.

2. *rubber gloves*, to protect against electrical hazards (see ANSI J6.6, Rubber Insulating Gloves)

3. *rubber, neoprene and vinyl gloves*, to protect against chemicals and corrosives

4. *leather gloves* (including the chrome-tanned cowhide or horsehide leather gloves used by welders), to resist sparks, moderate heat, chips and rough objects

5. *knit cotton gloves*, to protect against dirt, slivers, chafing or abrasion

6. *disposable plastic gloves*, to protect against liquids, greases, oils, solvents and dusts

7. *aluminized gloves,* to protect against burns and discomfort when the hands are exposed to sustained conductive heat.

Aluminized gloves should be substituted for asbestos gloves in the school shop.

Style of Cuff

When choosing hand protectors for a certain job, the style of cuff is as important as the glove material. Gloves which have no cuff offer no wrist protection. They can be used only for materials handling operations and general work where there is little danger of sparks, molten metal or irritating chemicals (either dry or liquid) getting into the glove.

A knit-wrist cuff offers only incidental wrist protection but keeps dust, dirt and dry irritants from getting in the gloves.

The gauntlet cuff protects the wrist and forearm and for special situations can extend all the way to the elbow. According to the capability of the glove material, it shields the lower arm against chemical, liquids, sparks, heat, flame, electricity, radiation or sharp edges.

Hand Leathers and Pads

Because they can be heavier and less flexible than gloves, hand leathers or hand pads may be more satisfactory than gloves for protection against heat, abrasion and splinters.

Selecting the Right Glove

The purchasing of protective gloves must be done wisely. Because protective gloves are usually purchased in quantity, a purchasing agent can assume too easily that the shop can get along with just one or two kinds. Of course it is not economical to specify a different glove for every job, but there is a sensible and safe middle ground which involves

- a shop operations hazard analysis
- a thorough knowledge of the types and uses of protective devices
- information about the budget, combined with knowledge of how gloves can be recycled.

Glove suppliers and their agents can offer useful recommendations to control specific problems.

BODY AND LEG PROTECTION

In the industrial/vocational education shop, the trunk and legs of student and instructor require protection from the hazards of molten metal, sparks, splashing liquids, heat and cutting.

Aprons for Flame and Heat Hazards

Welders need aluminized aprons or aprons of fire-resistant fabric or leather. Because of the carcinogenic properties of asbestos, it is recommended that asbestos aprons be banished from the industrial/vocational education shop.

The bib type covers the chest, waist and knees or ankles, while the waist type lacks the chest-covering bib. Some welders prefer to combine cape sleeves (full sleeves attached to a bib or short jacket which covers the chest) with leggings or split-leg aprons.

Aprons for Impact and Cut Hazards

Kickback aprons and aprons made of metal mesh or leather reinforced with metal studs offer another kind of body protection. The kickback apron shields the midsection against severe blows as in the kickback of stock during sawing operations. Metal mesh aprons prevent cuts from sharp tools or materials. Aprons made of leather studded with metal staples provide general protection against cuts, impact and abrasion.

Clothing for Chemicals and Liquid Hazards

Whenever there is the danger of splashing chemicals, all parts of the body that might be exposed must be protected. In addition to protecting the eyes, hands and arms, the student needs to protect his body with a coverall, overall, coat or apron. These garments are made of such materials as oiled fabric, natural or synthetic rubber, plastic, plastic-coated fiber, and so forth.

FOOT PROTECTION

Personal protective footwear can protect feet against such injuries as might result from falling objects, rolling objects (e.g., barrels, wheels, heavy pipe) or accidental contact with edged tools or sharp sheet metal. Protective footwear falls into two main classes —safety shoes or foot guards.

Safety Shoes

The Office of Technical Services of the Division of Safety, U.S. Department of Labor, has designated five principal types of safety shoes:

1. safety-toe shoes
2. conductive shoes
3. electrical hazard shoes
4. explosives-operations (nonsparking) shoes

5. foundry (molders) shoes.

Because it is unlikely that the last two types would be used in the industrial/vocational education shop, we will eliminate them from our discussion.

Safety-Toe Shoes

Safety-toe shoes provide protection to the toes by incorporating into the construction of the shoe a steel toe box or its equivalent. The toe box adds little to the weight or cost of the shoe, and a well made and properly fitted safety shoe is as comfortable as any other.

Safety toes are incorporated in leather and rubber boots, oxfords and leather shoes. Soles may be of leather, rubber, cord or wood. Plastic instep guards may be part of the shoe.

The ANSI label and class will be marked in the shoe. ANSI Z41.1, Men's Safety-Toe Footwear, divides footwear into three classes based on its ability to meet the minimum requirements for both compression and impact.

MINIMUM REQUIREMENTS
OF AMERICAN STANDARD Z41

Classification	Compression (pounds)	Impact (pounds)	Clearance (inches)
75	2500	75	16/32
50	1750	50	16/32
30	1000	30	16/32

2500 lbs. = 1134 kg.
1750 lbs. = 794 kg.
1000 lbs. = 454 kg.
75 lbs. = 34 kb.
50 lbs. = 23 kg.
30 lbs. = 14 kg.

16"–32" = 41–81 cm.

Selection Criteria

As with other types of protective devices, it is important that the extent of hazards be carefully assessed. Suppose that a supervisor makes an incorrect appraisal of the potential impact of a falling object which is 70 ft./lbs. and purchases class 30 foot protection. What will happen? Under the stress of impact, the toe box may provide insufficient protection and the victim will be injured. For general industrial/vocational education shop use, a class 75 box toe capable of supporting a static load of 2,500 pounds with an impact strength of 75-foot pounds is recommended.

Conductive Shoes

Conductive soles and heels drain off static charges so as to avoid the creation of static electricity in locations with a fire or explosion hazard.

Electrical Hazards Shoes

Electrical hazard shoes are made of leather. No metal is used in their construction except in the toe box, which is insulated from the shoe.

Foot Guards

Some basic types of foot guards are plastic, aluminum alloy or galvanized steel coverings which attach to the shoes temporarily by means of a heel strap. Foot guards protect both the toe and instep against falling or rolling objects.

Foot and Shin Guards

A combination foot and shin guard protects both foot and shin against flying particle hazards. The shin guard is made of the same material as the foot guard, is hinged to it and held in place by straps around the leg.

SUMMARY

Personal protective equipment is no substitute for engineering controls. As a supplement to safe work practices, however, PPE provides safeguards against hazards common in the industrial/vocational education shop: flying particles, molten metal, chemical exposure, splashing liquids, excessive noise, sharp objects, etc. If shop operations and processes are to take place in an environment where hazards have been evaluated and are being controlled, equipment must be selected wisely, maintained properly and used carefully.

NOTES

1. *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976) p. 51.
2. Adapted from *Fundamentals of Industrial Hygiene*, 2nd ed. (Chicago: National Safety Council, 1979), p. 717.
3. This section is adapted from *Respiratory Protection: An Employer's Manual* (Cincinnati: NIOSH, 1978), pp. 20—22.

QUESTIONS AND ANSWERS

1. What is the major shortcoming of personal protective equipment?

Personal protective equipment does nothing to reduce or eliminate the hazard.

2. What are the six major factors to be considered in the purchase of protective equipment?

a. What is the extent of the hazard?

b. Is the degree of protection in proportion to the seriousness of the hazard?

c. To what extent does the equipment interfere with the student's performance?

d. Is the equipment approved by the appropriate agencies?

e. What is the equipment's quality?

f. What is the equipment's cost?

3. Name three kinds of protection offered by eye protectors.

Any three from among the following:

a. protection against flying particles

b. protection against fumes and liquids

c. protection against hot splashing metals

d. protection against light rays.

4. What are the three basic types of personal hearing devices?

a. disposable pliable material

b. ear plugs

c. cup-type protectors

5. Name three factors to be considered in selecting respiratory protection.

Any three from among the following:

a. the nature of the hazardous process or operation

b. the type of respiratory hazard

c. the period of time for which respiratory protection must be provided

d. the location of the hazard area in relation to the nearest source of uncontaminated respirable air

e. the functions and physical characteristics of respiratory protective devices.

6. Why cannot hand protection devices shield against cuts and slivers when machinery is being operated?

The gloves themselves would become a hazard. They could snag in the revolving parts and pull the hand into the machinery.

7. Name three hazards for which body protection is available.

a. flame and heat

b. impact and cutting

c. chemicals and splashing liquids

8. What is a safety-toe shoe?

A safety-toe shoe incorporates into its construction a metal toe box to protect the toes.

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"Work Gloves," *National Safety News (July 1978), pp. 78–82.*

APPENDIX

RESPIRATORS: THEIR TYPES, USES AND MAINTENANCE

CLASSES OF RESPIRATORS

The three major classes of respirators are:

1. air-purifying respirators
2. supplied-air respirators
3. self-contained breathing devices.

Each class has various characteristics, advantages, limitations and subcategories. Federal regulations applying to respiratory protective devices are contained in 30 CFR 11 and 29 CFR 1910.134. The latter, OSHA Standard on Respiratory Protective Equipment, is reprinted in its entirety in *Fundamentals of Industrial Hygiene*, 2nd ed. (Chicago: National Safety Council, 1979), which is an important source for much of the following information. Another valuable source is ANSI Z88.2, American National Standard Practices for Respiratory Protection.

AIR-PURIFYING RESPIRATORS

Sometimes called dust, mist or fume respirators, air-purifying respirators by their filtering action remove contaminants from the atmosphere before they can be inhaled. Various chemicals can remove specific gases and vapors, and mechanical filters remove particulate matter.

There are four basic types of air-purifying devices:

1. mechanical filter respirators
2. chemical cartridge respirators
3. combinations of chemical cartridge and mechanical filter respirators
4. gas masks.

Advantages

Air-purifying devices are small, relatively inexpensive and easily maintained. Because of the various combinations of facepieces, mouthpieces, filters, cartridges and canisters available, the devices can be tailored to the particular shop situations.

Limitations

Air-purifying respirators cannot be used in oxygen-deficient atmospheres or where the air contaminant level exceeds the specified concentration limitation of the device. Seals on quarter-mask, half-mask and mouthpiece respirators are not always reliable, nor do these respirators protect the eyes or skin.

1. Mechanical (Particulate) Filter Respirators

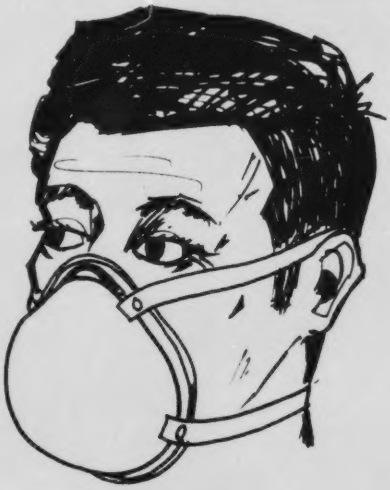
Mechanical filter respirators offer protection against particulate matter, including dusts, mists, metal fumes and smokes, but they do not provide protection against gases, vapors or oxygen deficiency. They consist essentially of a facepiece (quarter mask, half mask or full-face) with a mechanical filter attached. Many kinds of mechanical respirators have filters specifically designed for the various classes of particulate matter.

Items to be considered in selecting mechanical respirators are:

1. the resistance to breathing offered by the filtering element
2. the adaptation of the facepiece to faces of various sizes and shapes
3. the efficiency in removing particulates of specific size ranges
4. the time required to clog the filter.

Single-Use Dust

The single-use respirator is a respirator which is disposed of after use. Either the air purifier is permanently attached to the facepiece or the entire facepiece is made of filter material. At present, these respirators are approved only for pneumoconiosis- or fibrosis-producing dusts such as coal dust, silica dust and asbestos.

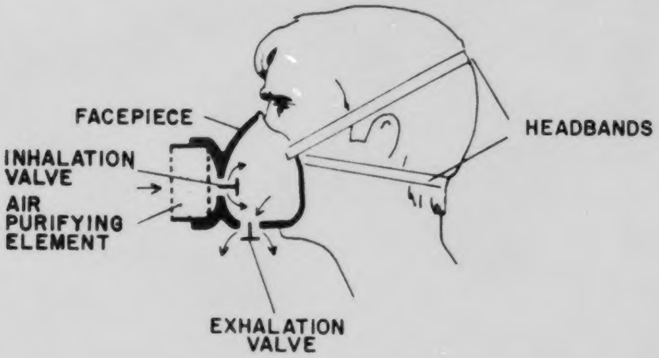


Single-Use Respirator

Reprinted from *Respiratory Protection: An Employer's Manual* (Cincinnati: NIOSH, 1978), p. 59.

Quarter-Mask Dust and Mist and Half-Mask Dust and Mist

The quarter-mask covers the mouth and nose, while the half-mask fits over the nose and under the chin. The half-mask produces a better facepiece-to-face seal than does the quarter mask and is therefore preferred for use against more toxic materials. Dust and mist respirators are designed for protection against dusts and mists whose TLV is greater than .05 mg/M^3 or 2 mppcf.



Typical quarter-mask respirator.

Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976), p. 29.

Quarter-Mask Fume and Half-Mask Fume

Quarter- and half-mask fume masks, similar to the quarter- and half-mask dust and mist masks, utilize a filter element which can remove metal fumes in addition to dusts and mists from the inhaled air. The filters are approved for metal fumes having a TLV above .05 mg/M^3 or 2 mppcf.

Half-Mask High Efficiency

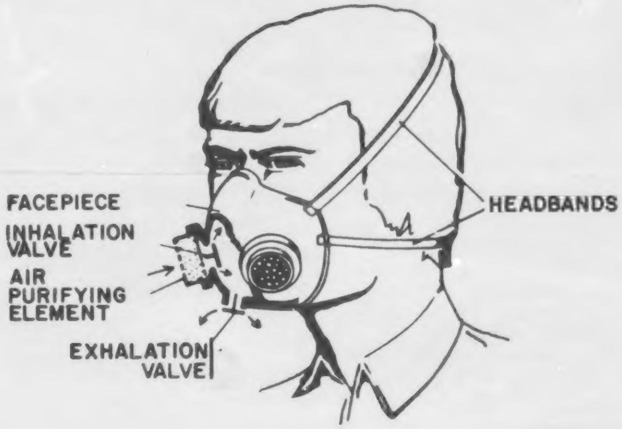
Half-mask high efficiency masks are the same as the respirators mentioned above but use a high efficiency filter. Because of this filter, they can be used against dusts, mists, fumes and combinations of those whose TLV is less than .05 mg/M^3 or 2 mppcf.

Full Facepiece

Full facepiece respirators cover the face from the hairline to below the chin. In addition to providing more protection to the face, the full facepiece respirators give a better seal than do the half- or quarter-mask respirators. Depending upon the type of filter used, these respirators provide protection against dusts, mists, fumes or any combination of these contaminants.

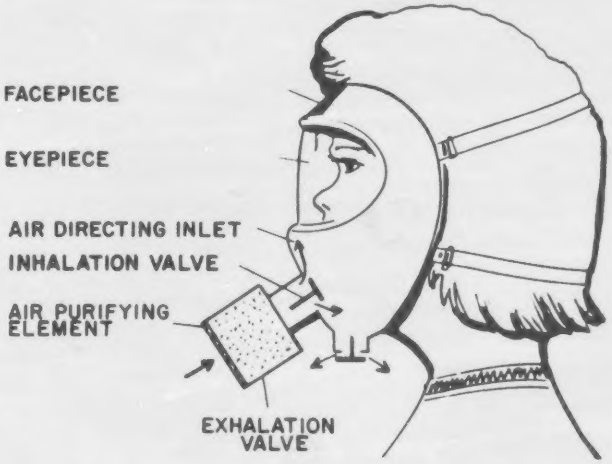
Limitations of Mechanical Filter Respirators

Air-purifying mechanical filter respirators offer no protection against atmospheres containing contaminant gases or vapors. They should not be used for abrasive blasting operations or in oxygen-


FACEPIECE
INHALATION VALVE
AIR PURIFYING ELEMENT
EXHALATION VALVE
HEADBANDS

Typical half-mask respirator.

Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976), p. 29.


FACEPIECE
EYEPIECE
AIR DIRECTING INLET
INHALATION VALVE
AIR PURIFYING ELEMENT
EXHALATION VALVE

Typical full-facepiece respirator.

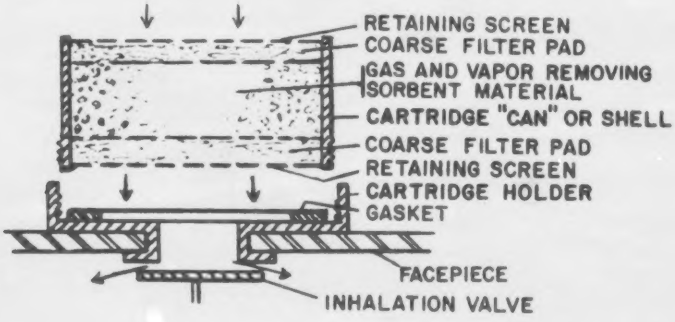
Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976), p. 30.

deficient atmospheres. Another limitation is that the air flow resistance of a mechanical respirator filter element increases as the quantity of particles it retains increases, thus increasing breathing resistance.

2. Chemical Cartridge Respirators

Chemical cartridge respirators use various chemical filters to protect against certain gases and vapors. They differ from mechanical filter respirators in that they use cartridges containing chemicals to remove harmful gases and vapors. Consisting of a facepiece connected directly to one or two small canisters of chemicals, they offer protection against intermittent exposure to light concentrations (10 ppm to 1000 ppm by volume, depending upon the contaminant) of gases and vapors.

The cartridge, a chemical filtering element which attaches directly to the facepiece, is constructed like this:


RETAINING SCREEN
COARSE FILTER PAD
GAS AND VAPOR REMOVING SORBENT MATERIAL
CARTRIDGE "CAN" OR SHELL
COARSE FILTER PAD
RETAINING SCREEN
CARTRIDGE HOLDER
GASKET
FACEPIECE
INHALATION VALVE

Typical chemical cartridge

Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976), p. 34.

Uses

Many gases and vapors in extremely low concentrations may cause nausea and headache. Sometimes they may produce chronic disorders which eventually may be fatal. Chemical cartridge respirators are particularly useful for guarding against

- organic vapors (e.g., acetone, alcohol, benzene, carbon tetrachloride, gasoline)
- acid gases (e.g., chlorine, sulfur dioxide)
- other gaseous materials (e.g., ammonia gases, mercury vapor).

Limitations

Chemical cartridge respirators have their limitations. They should not be used against gaseous material which:

1. is extremely toxic in very small concentrations
2. cannot be detected clearly by odor. Odor is necessary to alert the student to the fact that the sorbent is saturated and that contaminated air is passing through the cartridge. Cartridges should be changed when the wearer smells the vapor.
3. is in concentrations which are highly irritating to the eyes, unless supplementary eye protection is used
4. is not stopped effectively by the chemical fills utilized (e.g., carbon monoxide).

3. Combination Mechanical Filter/Chemical Filter Respirator

The third category of air-purifying devices belongs to combination mechanical filter/chemical filter respirators, which utilize dust, mist or fume filters with a chemical cartridge for dual or multiple exposure. Respirators with independently replaceable mechanical filters are sometimes used for this type of unit because the dust filter normally plugs before the chemical cartridge is exhausted.

One type of unit has a back-mounted filter element. It is especially well suited for spray painting and welding operations, where the air contaminant is concentrated in front of the student.

4. Gas Masks

Gas masks consist of a facepiece connected by a flexible tube to a canister. Contaminated air is purified by chemicals in the canister (see Figure 39). Gas masks offer respiratory protection against specific gases, vapors and particulate matter. They are compact, economical, easy to operate and easy to maintain. They are suitable for ventilating areas not subject to rapid change in air contaminant levels.

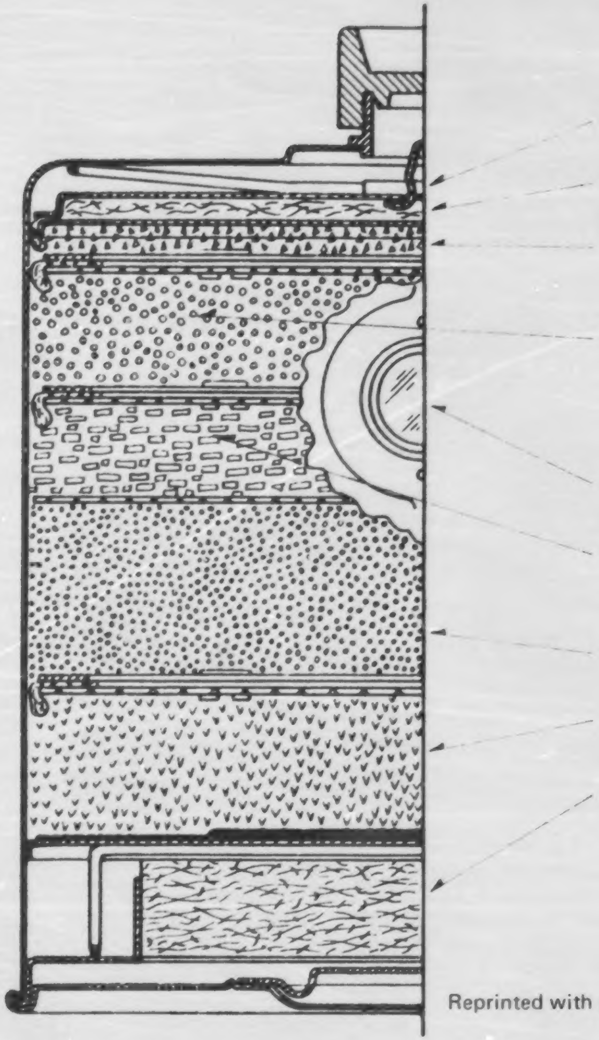
Types of Gas Masks

Various gas masks have been tested and approved by the U.S. Bureau of Mines for respiratory protection against specific gases and vapors specified on the label. OSHA regulations require that each gas mask canister be labeled and color coded to indicate the type of protection afforded (see Table 21).

Chin-type canisters, because of their smaller size, should be limited to concentrations not in excess of .5 percent by volume. They

CROSS SECTION OF M-S-A® MODEL "SW" TYPE N WINDOW-CATOR® OVAL CANISTER

BUREAU OF MINES APPROVAL NO. 14F-66A



SPRING holding chemical layers in position.

FILTER for Dusts.

PURE ANHYDROUS CALCIUM CHLORIDE, which acts as a Dryer, preventing moisture from reaching the "Hopcalite*" Catalyst.

"HOPCALITE*" Catalyst acts to convert Carbon Monoxide (CO) to Carbon Dioxide (CO_2) by uniting the Oxygen (O_2) in the air to the Carbon Monoxide (CO) thus forming Carbon Dioxide (CO_2) which is a relatively harmless gas. It also has considerable Absorbing Powers for Organic Vapors and Acid Gases.

WINDOW INDICATOR warns user when canister is no longer effective against CO.

MOLECULAR SIEVE, which acts as an absorber of Ammonia; also as a Dryer, preventing moisture from reaching the "Hopcalite*" Catalyst.

CAUSTITE for absorbing Acid Gases.

ACTIVATED CHARCOAL for absorbing Organic Vapors.

ULTRA HIGH EFFICIENCY FILTER for filtering toxic dusts, fumes, mists, fogs and smokes including radioactive particulates.

Reprinted with permission of Mine Safety Appliances Company.

Figure 39

Table 21

COLORS OR COMBINATION OF COLORS USED FOR GAS MASK CANISTERS

Atmospheric contaminants to be protected against	Colors assigned*
Acid gases	White
Hydrocyanic acid gas	White with ½-inch green stripe completely around the canister near the bottom
Chlorine gas	White with ½-inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gas	Green with ½-inch white stripe completely around the canister near the bottom
Carbon monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with ½-inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, except tritium and noble gases	Purple (magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors.	Canister color for contaminant, as designated above, with ½-inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with ½-inch gray stripe completely around the canister near the top

*Gray shall not be assigned as the main color for a canister designed to remove acids or vapors.

NOTE: Orange shall be used as a complete body, or stripe color to represent gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

Note that additional requirements for respiratory protection are now being included by OSHA in individual standards as, for example, in 1910.1001(d), Asbestos; 1910.1017(g), Vinyl Chloride; 1910.1028(g), Benzene Emergency Temporary Standard; and 1910.1029(g), Coal Tar Pitch Emissions.

Reprinted from *General Industry OSHA Safety and Health Standards (29 CFR 1910.134),* U.S. Department of Labor, November 1978.

may also be used against dusts and mists having a time-weighted average threshold limit value of not less than .05 mg/M^3 or two million particles per cubic foot.

The length of time that a gas mask provides protection depends upon

- the type of canister
- the concentration of contaminants in the air
- the breathing rate of the user
- the humidity.

Limitations

Gas masks are subject to the following limitations:

1. Their use must be restricted to atmospheres which contain sufficient oxygen to support life.
2. Exposure concentrations must not exceed the specific limitations.
3. They should not be used against a gas or vapor with poor warning properties unless they have an indicator or timer that shows when the canister should be changed.

SUPPLIED-AIR RESPIRATORS

The second class of respirators delivers uncontaminated air through a supply hose connected to the wearer's facepiece. There are essentially two major groups of supplied-air respirators: the air line respirator and the hose mask with or without a blower.

1. Air Line Devices

Air line respirators use a stationary source of compressed air delivered through a high-pressure hose. A trap and filter are installed in the compressed air line ahead of the masks to separate oil, water, grit or other matter from the airstream. Air line devices can be equipped with half- or full-face masks, helmets or hoods, or the devices can come as a complete suit. Air line respirators can be used for protection against particulates, gases or vapors.

A great advantage of air line respirators is that they can be used for long continuous periods. They provide a high degree of protection against contaminants.

Classes

There are three basic classes of air line respirators:

1. constant flow, which has a regulated amount of air fed to the facepiece and is normally used where there is an ample air supply (such as that provided by an air compressor)
2. demand flow, which delivers air only during inhalation and is used where air supply is restricted to high-pressure compressed air cylinders
3. positive pressure flow, which provides a positive pressure during both inhalation and exhalation, avoiding both the possible inward leakage caused by the negative pressure during inhalation which is part of the demand system and the relatively high air consumption of the constant flow system.

Limitations

Air line respirators cannot be used in atmospheres immediately dangerous to life or health because the user is completely dependent on the integrity of the air supply hose and the air source. If something happens to either the hose or air supply, the user cannot escape from the contaminated area without endangering his life. Extreme care must be taken to ensure that the source of air is free of hazardous substances such as carbon monoxide and oil mist.

Compressors or similar devices must be situated to avoid entry of contaminated air into the system. Alarms must be installed on compressors to indicate compressor failure and overheating, as well as excessive levels of carbon monoxide.

300' = 91 m.

Air line hose never may exceed 300 feet in length. This requirement limits the wearer to a fixed distance from the air supply source. The hose must be protected from objects which could cut or puncture it during use. Connections on the air line must be airtight.

2. Hose Masks

Hose masks supply outside air to the wearer through a length of hose. They are available either without a blower or with a power-driven or hand-operated blower.

Masks with Blowers

NIOSH/MSHA have approved hose masks with blowers for respiratory protection in any atmosphere—regardless of the degree of contamination or oxygen deficiency—*if* clean, breathable air can be reached within the distance of the permissible hose length (up to 300 feet), and *if* there is a person standing by with suitable rescue equipment.

300' = 91 m.

1" = 2.6 cm.

The air hose must have a large inside diameter (approximately one inch) so that, in case of blower failure, the wearer can breathe through the hose while escaping from the contaminated area. The hose must be able to withstand crushing weight and be highly resistant to petroleum vapors.

Hose Masks without Blowers

75' = 23 m.

Hose masks without blowers are used when uncontaminated air can be reached within 75 feet. Such units carry only limited approval and cannot be used in atmospheres immediately dangerous to life and health.

SELF-CONTAINED BREATHING APPARATUS (SCBA)

Self-contained breathing apparatus (SCBA), the third class of respirator, provides complete respiratory protection against toxic gases and oxygen deficiency. The SCBA allows the user to carry a respirable breathing supply and eliminates the need for a stationary air source to provide breathable air. The wearer is independent of the surrounding atmosphere because he is breathing with a system admitting no outside air. This allows comparatively free movement over an unlimited area.

In an environment that contains a substance that is dangerously irritant or corrosive to the skin, a self-contained breathing apparatus must be supplemented by impervious clothing.

Types

There are four basic types of SCBAs:

1. oxygen cylinder rebreathing
2. self-generating
3. demand
4. positive pressure.

The first two are closed circuit; the second two are open circuit systems.

Closed Circuit

In the closed circuit devices, air is rebreathed after the exhaled carbon dioxide has been removed and the oxygen content restored. These devices are designed primarily for one- to four-hour use.

Oxygen Cylinder Rebreathing

This type consists of a relatively small cylinder of compressed oxygen, reducing and regulating valves, a breathing bag, facepiece or mouthpiece plus noseclip and a chemical container to remove carbon dioxide from the exhaled breath.

Self-Generating

The self-generating type uses the principle of rebreathing, but it has no mechanical operating components. It has a chemical canister that evolves oxygen and removes the exhaled carbon dioxide. The wearer, using the canister, makes his own oxygen instead of drawing it from a compressed gas cylinder or liquid oxygen source.

Open Circuit

Open circuit devices have an air supply which lasts from three to thirty minutes, depending on the respirator. When compared with rebreathing types, they are relatively inefficient because the exhaled air, which is still rich in oxygen, is released into the atmosphere instead of being used again.

Demand

All the different models of demand type apparatus designed for specific applications consist of a high-pressure air cylinder, a demand regulator connected either directly or by a high-pressure tube to the cylinder, a facepiece and tube assembly with exhalation valve or valves and a method of mounting the apparatus on the body. After putting in the facepiece, the wearer opens the cylinder valve. The airflow is automatically regulated to the desired level to accommodate for varying breathing needs. The exhaled air passes through a valve in the facepiece to the surrounding atmosphere.

Positive Pressure

Positive pressure apparatus uses the same principle as positive pressure air line respirators. They are used in the same circumstances, namely where the toxicity is such that the potential facepiece leakage of demand apparatus presents an intolerable hazard.

MEDICAL ASPECTS OF USING RESPIRATORY EQUIPMENT

The use of any type of respirator may impose some physiological stress on the user. Air-purifying respirators, for example, make inhaling more difficult because the filter or cartridge impedes the flow of air; exhaling is more difficult because the expired air must force open a valve. The special exhalation valve on an open circuit pressure-demand respirator requires the wearer to exhale against significant resistance. The bulk and weight of a SCBA—up to 35 pounds—can be a burden. Someone using an air line respirator or hose mask may have to drag around up to 300 feet of hose.

35 lbs. = 16 kg.

300' = 91 m.

All of the above factors can increase significantly the user's workload. Those requiring respiratory equipment should have a medical examination to determine whether they have sufficient cardiovascular and pulmonary fitness to accommodate the additional physiological stress.

MAINTAINING RESPIRATORS

In large programs where respiratory protective equipment is used routinely, respirators should be cleaned and disinfected daily. In small programs where respirators are used occasionally, weekly or monthly cleaning and disinfecting are appropriate. Individual users who maintain their own respirators should be trained in the cleaning of respirators. The following suggestions are adapted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976).

Methods of Cleaning

Two methods of cleaning can be adapted to the industrial/vocational education shop:

1. The respiratory protection equipment may be washed with detergent in warm water, using a brush, thoroughly rinsed in clean water and then air-dried in a clean place. Care should be taken to prevent damage from rough handling. This method is an accepted procedure for a small respirator program or a program where each user cleans his own respirator.

2. A standard domestic-type clothes washer may be used if a rack is installed to hold the facepieces in a fixed position. (If loose facepieces are placed in a washer, the agitator may damage them.) This method is especially useful in large programs where respirator usage is extensive.

Detergents and Disinfectants

If possible, detergents containing a bactericide should be used. Organic solvents should not be used because they can deteriorate the rubber facepiece. If a detergent containing a bactericide is not available, a regular detergent may be used, followed by a disinfecting rinse. Reliable disinfectants may be made from some available household solutions.

- Hypochlorite solution (50 ppm of chlorine) made by adding approximately two tablespoons of chlorine bleach per gallon of water. A two-minute immersion disinfects the respirators.

- Aqueous solution of iodine (50 ppm) made by adding approximately one teaspoon of tincture of iodine per gallon of water. A two-minute immersion is sufficient and will not damage the rubber and plastic in the respirator facepiece.

Check with the manufacturer to find out the proper temperature for the solution.

If the respirators are washed by hand, a separate disinfecting rinse may be provided. If a washing machine is used, the disinfectant must be added to the rinse cycle, and the amount of water in the machine at that time will have to be measured to determine the correct amount of disinfectant to be added.

Rinsing
140°F = 60°C

The cleaned and disinfected respirators should be rinsed thoroughly in clean water (140°F maximum) to remove all traces of detergent, cleaner, sanitizer and disinfectant. This is very important to prevent dermatitis.

Drying

The respirators may be allowed to dry by themselves on a clean surface. They also may be hung from a horizontal wire, like drying clothes, but care must be taken not to damage the facepieces.

Storage

All the care that has gone into cleaning and maintaining a respirator can be negated by improper storage. Respiratory protective equipment must be stored so as to protect it from dust, sunlight, heat, extreme cold, excessive moisture and damaging chemicals. Leaving a respirator unprotected—on a workbench or in a tool cabinet or tool box among heavy wrenches—can lead to damage of the working parts or permanent distortion of the facepiece, making the respirator ineffective.

After the respirators are cleaned and disinfected, they should be placed individually in heat-sealed or reusable plastic bags until reissue. They should be stored in a single layer with the facepiece and exhalation valve in a more or less normal position to prevent the rubber or plastic from taking a permanently distorted "set."

INSPECTION

An important part of a respirator maintenance program is the inspection of the devices. If carefully performed, inspections will identify damaged or malfunctioning respirators. All respiratory protective equipment must be inspected

- before and after each use
- during cleaning.

Equipment designated for emergency use must be inspected

- after each use
- during cleaning
- at least monthly.

Self-contained breathing apparatus must be inspected

- at least monthly.

Record Keeping

A record must be kept of inspection dates and findings for respirators maintained for emergency use.

CORRECTING DEFECTS[3]

The following section itemizes some primary defects to look for when inspecting respirators. Information within the parentheses suggests appropriate action to be taken when defects are discovered.

Air-Purifying Respirators

1. *Air-Purifying Respirators* (mechanical filter, chemical cartridge, combination mechanical filter/chemical cartridge, gas mask)

   a. rubber facepiece—check for:
      - excessive dirt (clean all dirt from facepiece)
      - cracks, tears or holes (obtain new facepiece)
      - distortion (allow facepiece to "sit" free from any constraints and see if distortion disappears; if not, obtain new facepiece)
      - inflexibility (stretch and massage to restore flexibility)
      - cracked, scratched or loose fitting lenses (contact respirator manufacturer to see if replacement is possible; otherwise, obtain new facepiece).

   b. headstraps—check for:
      - breaks or tears (replace head-straps)
      - loss of elasticity (replace head-straps)
      - broken or malfunctioning buckles or attachments (obtain new buckles)
      - excessively worn serrations on the head harness which might allow the facepiece to slip (replace headstrap).

   c. inhalation and exhalation valves—check for:
      - detergent residue, dust particles, human hair or dirt on valve or valve seat (clean residue with soap and water)
      - improper insertion of the valve body in the facepiece or improper installation of the valve in the valve body (correct insertion and installation)
      - cracks, tears or distortion in the valve material or valve body (contact manufacturer for instructions)
      - missing or defective valve cover (obtain valve cover from manufacturer).

   d. filter element(s)—check for:
      - proper filter for the hazard
      - approval designation
      - missing or worn gaskets (contact manufacturer for replacement)

- worn threads, both filter threads and facepiece threads (replace filter or facepiece, whichever is applicable)
- cracks or dents in filter housing (replace filter)
- deterioration of gas mask canister harness (replace harness)
- service life indicator or end of service date; or, in the case of a gas mask, expiration (contact manufacturer to find out if your filter element has one; if not, ask what will indicate the "end of service").

e. corrugated breathing tube (gas mask)—check for:
  - cracks or holes (replace tube)
  - missing or loose hose clamps (obtain new clamps)
  - broken or missing end connectors (obtain new connectors).

Supplied-Air Respirators

2. *Supplied-Air Respirators*

a. check facepiece, headstraps, valves and breathing tube as for air-purifying respirators (1.a—c and e above).

b. hood helmet, blouse or full suit—check for:
  - rips and torn seams (if unable to repair the tear adequately, replace)
  - headgear suspension (adjust for individual fit)
  - cracks or breaks in faceshield (replace faceshield)
  - intact protective screen, which fits correctly over the faceshield of abrasive blasting hoods and blouses (obtain new screen).

c. air supply systems—check for:
  - breathing air quality
  - breaks or kinks in air supply hoses and end-fitting attachments (replace hose and/or fitting)
  - tightness of connections
  - proper setting of regulators and valves (consult manufacturer's recommendations)
  - correct operation of air-purifying elements and carbon monoxide or high-temperature alarms.

Self-Contained Breathing Apparatus

3. *Self-Contained Breathing Apparatus*—consult manufacturer's literature.

UNIT 15

MACHINE GUARDING

METHODS Lecture and Demonstration — **LENGTH: 60 Minutes**

PURPOSE To show how machine guarding contributes to the total hazard control program in the industrial/vocational education shop.

OBJECTIVES To introduce the participant to:

1. The hazardous mechanisms which need to be safeguarded
2. The places on machinery where guarding is required
3. The basic types of guards
4. Characteristics of good guards
5. Specific guarding requirements associated with equipment commonly encountered in the industrial/vocational education shop.

SPECIAL TERMS

1. Rotary Motion
2. Reciprocating Motion
3. Inrunning Nip Point
4. Point of Operation
5. Fixed Enclosure Guard
6. Interlocking Guard
7. Ripping
8. Crosscutting
9. Flanges

INSTRUCTOR MATERIALS

Lesson Plan
35 mm Slides, Projector and Screen
Chalk Board/Chalk

TRAINEE MATERIALS

Participant Outlines and Supplementary Materials

UNIT 15

MACHINE GUARDING

INTRODUCTION

The National Safety Council estimates that nearly 1/5 of all permanent partial disabilities result from injuries associated with machinery. Poorly designed, improperly guarded or unguarded machinery are deterrents to the educational process and well-being of students, instructors and other school personnel.

Machine guarding is of the utmost importance in protecting students in the industrial/vocational education shop from the hazards associated with operating machinery. In fact, it could be said that the degree to which machines are guarded in the shop is a reflection of the administration's interest in providing a safe workplace. Machine guarding is not optional but required. OSHA regulations clearly state that points of operation and power transmission *shall* be guarded.

People cannot always be relied upon to act safely enough around machinery in motion to avoid accidents. Even the well coordinated and highly trained person may commit an error which could lead to injury and death. An effective guard will allow students to be more comfortable around machinery because he will know that he is protected from hazards. On the other hand, a poorly designed or inadequate guard can be more dangerous than no guard at all because students will trust it for protection it cannot provide.

Definition of Guarding

Sources to be Guarded Against

The National Safety Council defines guarding as "any means of effectively preventing personnel from coming in contact with the moving parts of machinery or equipment which could cause physical harm to the personnel."[1] Machine guarding protects against and prevents injury from the following sources:

1. direct contact with the moving parts of a machine
2. work in process making contact with personnel (e.g., kickbacks on a circular ripsaw, metal chips from a machine tool operation, splashing of chemicals or hot metal)

3. mechanical failure
4. electrical failure
5. human failure from any of various causes (e.g., curiosity, distraction, fatigue, worry, anger, illness, zeal, laziness, deliberate risk-taking).[2]

MECHANICAL MOTIONS

Before we ask what mechanisms need safe-guarding, we first must determine what is meant by machinery motion.

All machinery movement employs one of three kinds of motion: rotary motion, reciprocating (back-and-forth) motion or a combination of these two. Each of these motions can produce crushing and shearing actions.

Rotary Motion

Rotary motion is found in simple rotating mechanisms, rotary cutting and shearing mechanisms, rotating mechanisms with inrunning nip points and screw or worm mechanisms. Rotary action is hazardous regardless of the speed, size or surface finish of the shaft. Even smooth, slowly rotating shafts can grip clothing or hair or force an arm or hand into a dangerous position.

Reciprocating Motion

Where reciprocating motion is used, the hazardous point comes when the moving part approaches or crosses a fixed part of the machine. (A back-and-forth motion could also be called transverse, depending on the position of the worker in relation to the machine.)

MECHANISMS REQUIRING GUARDS

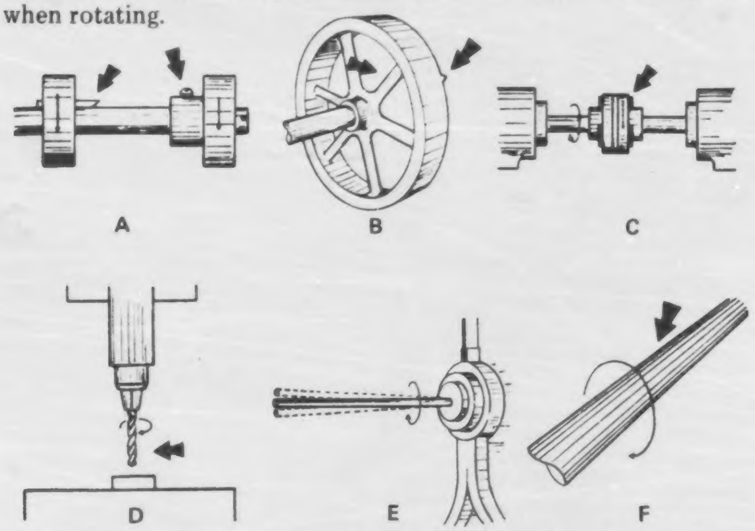
Mechanisms using these motions always need guarding if they are exposed. They can be divided into the following groups:

1. rotating mechanisms
2. cutting or shearing mechanisms
3. inrunning nip points
4. screw or worm mechanisms
5. forming or bending mechanisms.[3]

A piece of equipment may employ more than one type of hazardous motion. For example, a belt and pulley drive is a hazardous rotating mechanism and also has hazardous inrunning nip points.

Rotating Mechanisms

A rotating part is dangerous unless it is guarded. Common hazardous rotating machine parts include vertical or horizontal transmission shafts, pulleys, belts, rod or bar stock projecting from lathes, set screws, flywheels and their cross members, drills, couplings and clutches (see Figure 40). The danger increases when such items as bolts, projecting keys or screw threads are exposed when rotating.



Rotating mechanisms that can seize and wind up loose clothing, belts, hair, and the like, should be provided with guards: a—projecting key and setscrew; B—spokes and burns; C—coupling bolts; D—bit and chuck; E—turning bar stock; and F—rotating shaft.

Reprinted with permission form *Supervisors Safety Manual,* 5th ed. (Chicago: National Safety Council, 1978), p. 298.

Figure 40

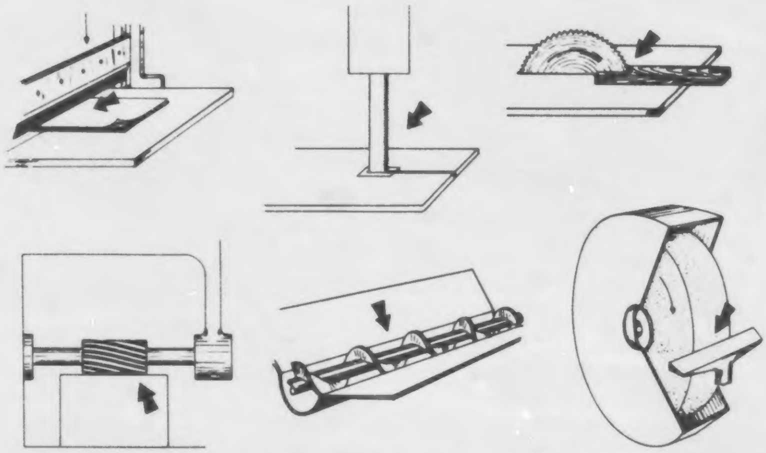
Cutting or Shearing Mechanisms

The hazards of cutting and shearing mechanisms lie at the points where a rotary cutting action is used or where the moving parts of a reciprocating mechanism approach or cross the fixed parts of the piece or machine (see Figure 41). Examples of machines using cutting and shearing mechanisms are band and circular saws, milling machines, lathes, grinding machines, abrasive wheels, shapers and drills and boring machines.

Inrunning Nip Points

An inrunning nip point is formed:

1. when two parts that are in contact with or close to one another rotate in opposite directions
2. when a part rotates over, under or near a stationary object.



Common cutting or shearing mechanisms. Protection should be provided for all variations of such hazards.

Protection against all variations of these common cutting and shearing mechanisms should be provided.
Reprinted with permission from *Supervisors Safety Manual,* 5th ed. (Chicago: National Safety Council, 1978), p. 301.

Figure 41

A nip point draws in objects or parts of the body and crushes, mangles or flattens them. Once an object is drawn in, it is difficult if not impossible to withdraw it. Examples of nip points are the points of contact between a belt and pulley, chain and sprocket, gear and rack and the squeeze spaces between shafts or rolls which are rotating close together and in opposite directions (see Figure 42).

Screw or Worm Mechanism

The hazards of screw or worm mechanisms are

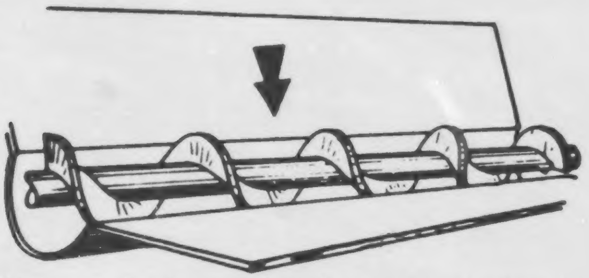
1. the shearing action set up between the moving screw and the fixed parts of the machine

2. the mangling or battering action created if a part is caught in the mechanism.

Screw or worm mechanisms are used for conveying, mixing or grinding materials.

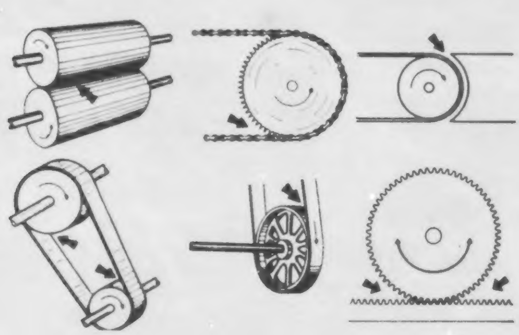
Forming and Bending

The hazard of all forming and bending mechanisms lies at the point where the punch or upper die approaches the lower die. In other words, the danger lies at the point of operation where stock



Worm mechanism employed in screw conveyor.

Reprinted with permission from *Guards Illustrated,* 3rd ed. (Chicago: National Safety Council, 1973), p. xv.



Typical inrunning nip points. Protection against such hazards is of prime importance to prevent accidents.

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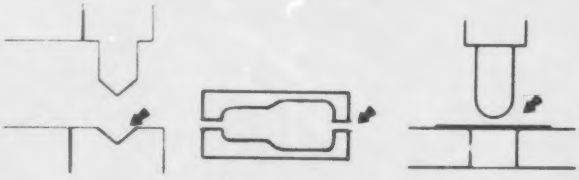
Figure 42

is inserted, maintained and withdrawn. Examples of such mechanisms are power, foot and hand presses, press brakes, metal shears and forging machines.



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WHERE GUARDING IS NECESSARY

Guarding should take place at two points:

1. the point of operation
2. the point where power is delivered to the machine.

Point of Operation Definition

The point of operation is that area on a machine where material is positioned for processing or change by the machine. It is the place where work is actually performed upon the material. OSHA defines it as "that point at which cutting, shaping, boring or forming is accomplished upon the stock."

OSHA Requirements

OSHA regulations (in 29 CFR 1910.212) mandate:

> The point of operation of machines whose operation exposes an employee to injury shall be guarded. The guarding devices shall be in conformity with any appropriate standards therefore, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

OSHA also has established requirements for the design, construction, application and adjustment of point of operation guards (29 CFR 1910.212). In general, point of operations guards must:

1. prevent entry into the point of operation by hands or fingers reaching through, over, under or around the guard
2. conform to the maximum permissible openings (see Table 22)
3. create no pinch point between the guard and moving machine parts
4. minimize the possibility of misuse or removal of essential parts by utilizing fasteners which the operator cannot remove readily
5. facilitate inspection
6. offer maximum visibility of the point of operation.

Point-of-operation guards must be constructed with a feed opening that is limited in size so that stock or material can be admitted

TABLE 22

MAXIMUM PERMISSIBLE OPENINGS

DISTANCE OF OPENING FROM POINT OF OPERATION HAZARD (in inches)	(in centimeters)	MAXIMUM WIDTH OF OPENING (in inches)	(in millimeters)
½ to 1½"	1.3 to 3.8 cm.	1/4"	6 mm.
1½ to 2½"	3.8 to 6.4 cm.	3/8"	10 mm.
2½ to 3½"	6.4 to 8.9 cm.	1/2"	13 mm.
3½ to 5½"	8.9 to 14.0 cm.	5/8"	16 mm.
5½ to 6½"	14.0 to 16.5 cm.	3/4"	19 mm.
6½ to 7½"	16.5 to 19.0 cm.	7/8"	22 mm.
7½ to 12½"	19.0 to 31.8 cm.	1 1/4"	32 mm.
12½ to 15½"	31.8 to 39.4 cm.	1 1/2"	38 mm.
15½ to 17½"	39.4 to 44.5 cm.	1 7/8"	48 mm.
17½ to 31¾"	44.5 to 80.0 cm.	2 1/8"	54 mm.

Adapated from General Industry OSHA Safety and Health Standards (29 CFR 1910.217), November 1978.

Guard Openings

into the danger zone but hands and fingers cannot. Guard openings are necessary for:

1. material—entrance, removal, scrap removal
2. vision—cutting, line, inspection, selection
3. lubrication—greasing, oiling, cleaning
4. adjustments—repairs, alterations, changes.

Maximum Safe Openings

3/4" = 19 mm.

Maximum safe openings are placed so that they do not permit the operator's fingers to reach the point of operation (see Table 22). Suppose it is necessary to provide a 3/4-inch opening between the bottom of the guard and the top of the feed table or between

3/4" = 19 mm.
5-1/2" = 140 mm.

openings in a guard for the feeding of material. In this case the diagram shows that a 3/4-inch opening is permissible to within 5-1/2 inches of the point of operation.

3/8" = 10 mm. 1/4" = 6 mm.
1-1/2" = 38 mm.

The average woman's finger (glove size 6-1/2) will go through a 3/8-inch opening. Therefore, for openings in any guard, use 1/4 inch as the allowable opening within 1-1/2 inches of the hazards. When installing guards with openings over 1/4 inch, tests should be carefully made by students, particularly girls, to make certain that the guard is effective before the machine is operated.

Point Where Power is Delivered

Distinct from point-of-operation guarding but complementary to it is guarding at the point where power is delivered to the machinery. This includes the entire power transmission apparatus. Because power transmissions are far more standardized and because it is not necessary to consider feeding material into the machine as with the point of operation situation, they are easier to guard effectively. The American National Standards Institute (ANSI) has established, in its Standard B15.1, a Safety Code for Mechanical Power Transmission Apparatus.

TYPES OF GUARDING

There are four basic types of guards which protect the worker from the motion of a machine:

1. fixed enclosure
2. interlocking
3. automatic
4. remote control, placement, feeding and ejecting.

Fixed Enclosure Guard

The fixed enclosure guard is preferable to all other types and should be used in every practicable case. It prevents access to dangerous parts at all times by enclosing the hazardous operation completely. It also confines flying objects.

Fixed guards may adjust to different sets of tools and dies and to various kinds of work. Once adjusted, they should not be moved or detached.

Fixed guards may be installed at the point where material is being processed and at other places where there may be a hazard when inserting or manipulating stock. They also may be used to prevent contact with rotating or reciprocating motions of machine members. Fixed enclosure guards are found on such machines as power presses, drills and milling machines.

Interlocking Guard

When a fixed enclosure guard cannot be used, an interlocking guard should be fitted onto the machine as the first alternative. The interlocking guard prevents operation of the control that sets the machine in motion until the guard is moved into position so that the operator is unable to reach the point of danger. When the guard is open and dangerous parts are accessible, the starting mechanism is locked. A locking pin or some other safety device prevents the main shaft from turning or other basic mechanisms from operating. When the machine is in motion, the guard cannot be opened. It stays closed until the machine has come to rest or has reached a fixed point in its travel.

Example

An interlocked press barrier guard is required on mechanical power presses. It must be interlocked with a press clutch control so that the clutch cannot be activated unless the guard (or the hinged or movable sections of the guard) is in the proper position.

Requirements for Interlocking Guards

An interlocking enclosure guard must do four things:

1. guard the dangerous point before the machine can be operated
2. stay closed until the dangerous part is at rest
3. prevent operation of a machine if the interlocking device fails
4. require the activation of a reset device to restart.

When gate guards or hinged enclosure guards are used with interlocks, they should be so designed that they enclose completely the point of operation before the operating clutch can be engaged.

Automatic Guard

When neither a fixed barrier nor an interlocking guard is practicable, an automatic protection device may be used. Such a device is less desirable than the two previously discussed.

An automatic guard acts independently of the operator, repeating its cycle as long as the machine is in motion. The device is usually operated by the machine itself through a system of linkage, through levers or by electronic means. Such a device must prevent the operator from coming in contact with the dangerous part of a moving machine or must be able to stop the machine quickly in case of danger.

Sweep devices are no longer approved by OSHA for safeguarding at the point of operation. Pull-away or hand-restraint types remove the operator's hands or fingers from the danger zone as the ram, plunger or slide closes on the piece upon which the work is being done. These types are being phased out and replaced with automatic electrical devices.

All electrical and electronic devices perform the same end function when energized. They interrupt the electric current just as if the "stop" button had been pushed.

Example

A jointer must have an automatic guard to cover the section of the head on the working side of the fence or gauge. This guard automatically adjusts itself to cover the unused portion of the head.

Application of Guards

All three of these devices—fixed enclosure, interlocking and automatic—can be used to guard points of operation. Only the fixed guard can guard power transmission components.

Remote Control, Placement, Feeding, Ejecting

Although they are not guards in the technical sense, certain methods can be used to accomplish the same effect; that is, to protect the operator from the hazardous point of operation. These methods may complement one of the other types of guards.

One example is a trip or control system which requires two hands to activate the machine. Such devices require simultaneous action of both the operator's hands on an electrical switch button, an air control valve or a mechanical lever. Because the operator must use both hands to give concurrent pressure, during the most hazardous part of the machine's operation, he cannot move his hands from the controls to the danger zone until the cycle has been completed. Removal of a hand from the control causes the machine to stop.

Stock may be fed automatically or semi-automatically by rolls, plungers, chutes, slide and dial feeds and revolving and progressive dies in conjunction with ram enclosures. This method will not admit any part of the body to the danger zone.

Special jigs or feeding and holding devices (e.g., pickers, grab bars, push sticks, long-handled tongs, hand die holders) may be used to manipulate stock at the point of operation and yet keep hands safe. Such hand tools for placing or removing material are to be used in conjunction with fixed enclosure, interlocking or automatic guards.

Mechanical or air-operated ejecting mechanisms may be used to remove parts, eliminating the need to place hands in the danger zone.

The theory behind these methods is that, if it is impossible to completely enclose or isolate the hazard, the next most effective device or combination of devices should be used to keep exposure to a minimum.

Selecting a Method of Guarding

Important considerations in selecting a method of machine guarding include:

- the type of operation
- the size or shape of stock
- the method of handling
- the physical layout
- the type of material
- the job requirements or limitations.

Machine Parts Which Require Guarding

Some machines require specific methods of guarding. These machines and methods will be discussed later in this unit. But all machines are regulated by the general requirement that points of operation and power transmission must be guarded. Federal regulations further mandate (29 CFR 1910.212):

> One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks.

Chain drives, shafting, coupling, keys, collars and clutches located seven feet or less above the ground, floor or working platform must be guarded to prevent accidental contact. V-belts and chain drives must be enclosed completely.

SOME GUARD REQUIREMENTS

Good engineering principles should be applied to the design and construction of each machine in order to eliminate hazards and to permit safe and efficient operation. When it is not possible to design hazards out of machinery, then suitable safeguards should be provided.

What are the requirements for an acceptable guard?

Protect Operator

1. It should give maximum protection to the operator.

Protect Others

2. It should protect others working close to or passing by the machine from coming in contact with moving parts.

Be a Permanent Part of the Machine

3. It should be considered a permanent part of the machine or equipment. OSHA regulations (29 CFR 1910.212) require that guards be affixed to the machine where possible. The guard should resist tampering or easy removal. It should be designed for the specific job and the specific machine, and its purpose and use should be evident, even to an uninformed student.

Be Convenient

4. It should be convenient. It should not interfere with the efficient operation of the machine, nor should it require continual adjustment or removal to accomplish certain work tasks. It should cause the operator no discomfort but should enable him to work with less tension.

Prevent Access to Danger Zone

5. It should prevent access to the danger zone during operation.

Allow Access for Servicing

6. It should allow access to the machine for servicing. Provisions should be made for inspecting, adjusting and making repairs on machine parts enclosed by guards without exposing the worker to moving parts. Lubrication of the machine should not require removal of the guard. Whenever possible, oil reservoirs should be located outside the guard, with the oil line leading to the point of lubrication.

Be Durable

7. It should be durable. It should be constructed of materials at least as durable as those used in any other part of the machine and should serve over a long period with minimum maintenance. It should resist normal wear and shock. The guard should be secured so that a blow to or vibration of the machine will not cause it to work loose,

break or fall into or off the area being guarded. It should resist fire and corrosion.

Be Easy to Repair

8. It should be easy to repair.

Not Create a Hazard

9. It must "not offer an accident hazard in itself" (OSHA 29 CFR 1910.212). All edges should be rolled and bolted to eliminate sharp or rough edges and corners. There should be no shear or pinch points, splinters, exposed bolts or other possible sources of injury.

Conform to Appropriate Standards

10. It must conform to the requirements of OSHA and/or the state inspection department having jurisdiction. Purchasing agents should be advised against "pre-OSHA" bargains, which eventually will cost more to rectify than the savings realized at the time of purchase. Where American National Standards apply, the guard should conform to or exceed these requirements.

GUARDS FOR SPECIAL SITUATIONS

There may be special situations in the industrial/vocational education shop where guards need to be made locally. It is essential that such guards meet the preceding requirements.

Making Guards to Fit Older Machinery

Many schools, particularly older ones, may be using an older machine which, though still serviceable, is not adequately guarded and for which guards cannot be purchased because of the machine's age. Often the cost of newer, more modern, guard-equipped machines is prohibitive. It then becomes necessary for guards to be designed and built locally.

Making Guards to Fit Non-Standard Machines

Some machines are of a standard type that has been converted or equipped to perform a special function. At the time of purchase, the machine may or may not have been equipped with guards. However, because of its specialized nature, the machine cannot carry a standard guard. Therefore, guards must be designed and built locally to provide adequate protection for the machine operators.

COMMON MACHINERY TO BE GUARDED

Thus far in this unit we have examined what mechanical motions need to be guarded, where guarding is necessary and types and characteristics of good guards. Now we will examine the guarding requirements of specific machinery found in industrial/vocational education shops.

OSHA Standards

Throughout our discussion we will refer to the relevant OSHA standards. OSHA has granted many states the right to develop and enforce their own occupational safety and health standards under their own state plans. The basic criterion for approving such plans is that they be "at least as effective as" the federal program. Because all approved state plans equal or surpass OSHA regulations in stringency, these regulations are cited as minimal standards. School districts and corporations must comply with the safety and health regulations of their own state plans. In states which have not adopted plans of their own, federal OSHA regulations provide guidance for the industrial/vocational education supervisor or instructor who wants to create a safe shop environment for himself and his students.

Woodworking Standards

We will begin our examination of guarding requirements with the equipment found in woodworking shops. A useful source for the instructor and supervisor is ANSI 01.1-1971, American National Standard Safety Requirements for Woodworking Machinery.

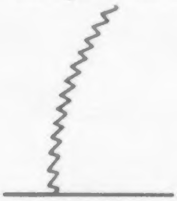
SAWS

Saws can be divided into many different categories, and terminology may vary from one shop to another. For our discussion, we will divide saws into two broad classes, circular and bandsaws.

Circular Saws

The circular, or table, saw is one of the most versatile machines in the industrial/vocational education shop. It uses many special types of blades for its operations. The most common are:

1. the ripsaw blade with teeth filed straight across, used to cut with the grain of the wood
2. the crosscut or cut-off saw blade, used to cut across the grain. The teeth are beveled and set, or bent, alternately right and left; that is, one tooth is bent to the right, the next to the left and so on.
3. the combination saw blade, used to crosscut, rip and miter. The smaller crosscut teeth are filed and set as they are on the crosscut saw; the larger rake or rip teeth are filed straight across.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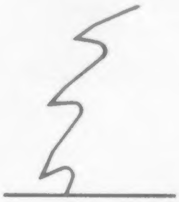
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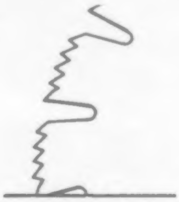
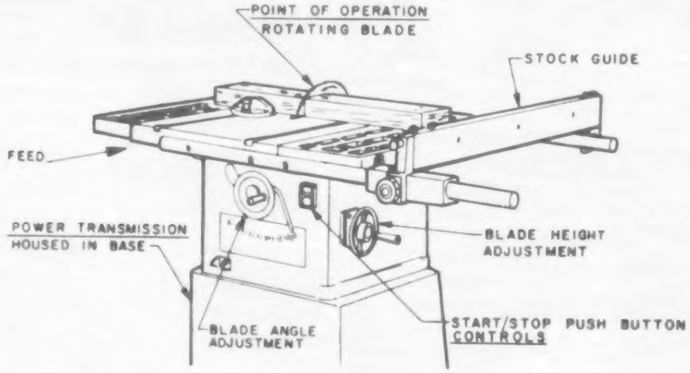

COMBINATION

In our discussion we will look first at hand-fed saws and self-feed saws. Then we will examine special kinds of circular saws, swing cutoff and radial saws. We will examine first the hand-fed saws: what they are, what hazards they present, what OSHA guarding regulations are required and what other guarding measures will ensure their safe use.

HAND-FED SAWS

The circular hand-fed saw can be either a ripsaw, a crosscut saw or a combination saw (see Figure 43, which illustrates a ripsaw being used for a crosscut operation). With this kind of power table saw, the operator first adjusts the blade height, then holds the stock and pushes it into the blade. A guide is used to maintain a straight cut. At the end of the cutting stroke, the operator must push the stock past the blade, or he must change positions at the saw so that he can pull the stock.



Unguarded circular saw.
Reprinted from *Machine Guarding–Assessment of Need* (Cincinnati: NIOSH, 1975), p. 23.

Figure 43

Mechanical and Operational Hazards

General hazards are inherent in the following: power transmission, point of operation, kickbacks and flying particles.

Power Transmission

The saw may be driven by an individual motor or from a line shaft, comprising belts, gears and pulleys. Though the power transmission is usually housed beneath the blade and enclosed, there are open units which expose the bottom portion of the blade.

Point of Operation

Accidental contact with the saw blade by the operator or others is possible, particularly because the operator is working very close to the point of operation.

Kickbacks

Kickbacks occur when the saw blade seizes the stock being cut and hurls it back toward the operator. Serious injuries may result. Kickbacks can be caused by unsafe operating methods (e.g., height not properly adjusted), improperly maintained equipment (e.g., blade not properly sharpened) or by lack of proper physical safeguards. Ripping operations are more hazardous than cross-cutting because of the greater likelihood of kickbacks.

Flying Particles

Sawdust, splinters and chips are thrown off as a result of the cutting action of the blade and can come in contact with the operator or others.

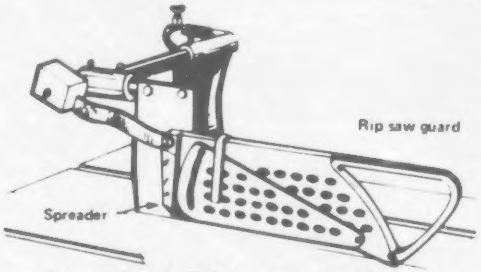
Hazard Control Point of Operation Guard

OSHA regulations (29 CFR 1910.213) mandate the machine guarding requirements. They state that each circular hand-fed ripsaw and each circular table saw

> . . . shall be guarded by a hood which shall completely enclose that portion of the saw above the table and that portion of the saw above the material being cut. The hood and mounting shall be arranged so that the hood will automatically adjust itself to the thickness of, and remain in contact with, the material being cut . . . The hood shall be of adequate strength to resist blows and strains incidental to reasonable operation, adjusting and handling and shall be so designed as to protect the operator from flying splinters and broken saw teeth. . . . The hood shall be so mounted as to insure that its operation will be positive, reliable and in true alignment with the saw; and the mounting shall be adequate in strength to resist any reasonable side thrust or other force tending to throw it out of line.

Filler Piece

In order to use the hood guard effectively when cutting narrow strips on circular ripsaws, a filler piece should be used. This piece



Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 122.

should be made of wood about two inches wide and should be about 3/4 inch thick, or slightly thinner than the thickness of the material being cut. It should be provided with cleats or brackets at the ends, so that it either will fit down over the front and back ends of the table or can be quickly attached to the fence or gauge.

2" = 50 mm.
3/4" = 19 mm.

The same statute mentioned earlier deals with the hazards of flying particles by requiring a spreader.

The statute requires that each circular hand-fed ripsaw and each circular crosscut table saw

> . . . shall be furnished with a spreader to prevent material from squeezing the saw or being thrown back on the operator. The spreader shall be made of hard-tempered steel, or its equivalent, and shall be thinner than the saw kerf. It shall be of sufficient width to provide adequate stiffness or rigidity to resist any reasonable side thrust or blow tending to bend or throw it out of position. The spreader shall be so attached that it will remain in true alignment with the saw, even when either the saw or the table is tilted, and should be placed so that there is not more than 1/2-inch space between the spreader and the back of the saw when the largest saw is mounted in the machine.

1/2" = 13 mm.

Kickbacks

Kickbacks on ripsaws are usually caused by one of the following:

1. failure to provide the required spreader
2. an improperly conditioned saw which allows material to pinch on the saw and rise from the table
3. improperly aligned gauge or rip fence
4. improperly conditioned or twisted grain lumber
5. improperly designed or mounted antikickback devices.[4]

Nonkickback Fingers

OSHA regulations require guards on ripsaws to protect against both kickbacks and flying material. They require:

> Each hand-fed circular ripsaw shall be provided with nonkickback fingers so located as to oppose the thrust or tendency of the saw to pick up the material or to

kick it back toward the operator. They shall be designed to provide adequate holding power for all the thicknesses of materials being cut.

Personal Protective Equipment

Operators should be required to use proper protective equipment, such as goggles and/or face shield each time the saw is operated. Where there is a danger of kickback from any operation, anti-kickback aprons must be provided and worn.

Long sleeves or other loose clothing should not be worn, nor should rings, bracelets or other jewelry. Long hair should be confined by hair nets or caps.

Power Transmission Guards

If saw parts are driven by belts that are exposed, belts and pulleys should be completely enclosed by sheet metal or heavy mesh guards, even though the saw may be partially fenced off or partially removed from other machines.

Operating Controls

Operating controls should be recessed or shrouded; in addition, an emergency stop button is recommended. A main power electrical disconnect switch is required.

Push Sticks

A push stick must be provided so that the operator will not use his hand to feed stock past the blade. This is especially important when cutting short or narrow stock.

Other Operating Methods

For safety reasons, a crosscut saw should not be used for ripping nor a ripsaw for crosscutting. Using the wrong saw makes the work harder and requires additional force to feed the stock. Work that can be done on self-feed machines should not be done on hand-fed machines.

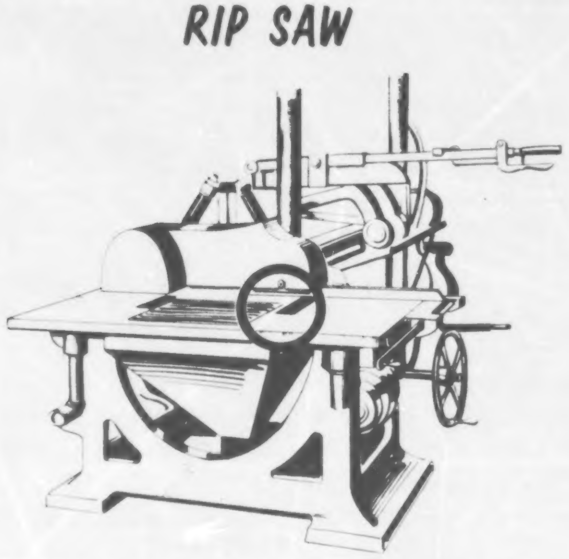
Long stock should not be crosscut. If the stock extends beyond one or both ends of the table, it may interfere with other operations or strike persons in the shop. A swing or pull saw should be used on such stock.

SELF-FEED SAWS

The self-feed (or power-feed) saw is equipped with rollers or a conveyor system to hold the lumber and force-feed it into the saw blade (see Figure 44).

Mechanical and Operational Hazards

The hazards are identical with those of hand-fed saws. There is an additional point of operation hazard. Not only can the operator accidentally come in contact with the saw blade, but also there is the danger of being pinched between the stock and the in-running rolls.



Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 18.

Figure 44

OSHA requires a hood or guard to protect against this hazard:

Hazard Control Point of Operation Guard

> Feed rolls and saws shall be protected by a hood or guard to prevent the hands of the operator from coming in contact with the in-running rolls at any point. The guard shall be constructed of heavy material, preferably metal, and the bottom of the guard shall come down to within 3/8 inch of the plane formed by the bottom or working surfaces of the feed rolls. This distance (3/8 inch) may be increased to 3/4 inch, provided the lead edge of the hood is extended to be not less than 5-1/2 inches in front of the nip point between the front roll and the work.

3/8" = 10 mm.

3/4" = 19 mm.
5-1/2 = 14 cm.

Feed rolls should be adjusted to the thickness of the stock being ripped. Insufficient pressure on the stock can contribute to kickbacks. The antikickback fingers required by OSHA should be checked regularly to make sure that they are sharp and that none of the fingers is bent. OSHA requires:

Antikickback Fingers

> Each self-feed circular ripsaw shall be provided with

sectional kickback fingers for the full width of the feed rolls. They shall be located in front of the saw and so arranged as to be in continual contact with the wood being fed.

Personal Protective Equipment

The personal protective equipment requirements are the same as for hand-fed saws.

Clearance

3' = 91 cm.

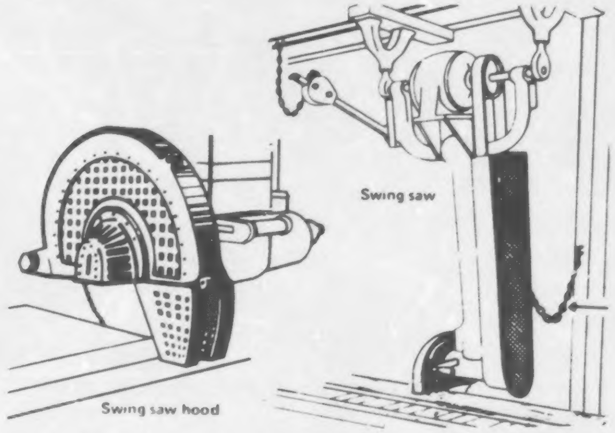
Because long stock is often ripped on self-feed ripsaws, the clearance at each working end of the saw table should be at least three feet longer than the longest material handled.

Emergency Stops

Emergency stop buttons should be provided, one for the operator and one for the offbearer.

SWING AND SLIDING CUTOFF SAWS

Swing and sliding cutoff saws are used for crosscutting operations. The swing saw, which is more common, is suspended from the roof or overhead. The operator pulls it forward like a pendulum (see Figure 45).



Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 126.

Figure 45

Mechanical and Operational Hazards

Hazards may be inherent in the power transmission and in the point of operation.

Power Transmission

This type of saw generally is driven by an individual motor with the saw attached directly to the motor shaft. It also may be driven with an individual motor by belt and pulleys.

Point of Operation

Accidents occur at the point of operation when:

1. the operator, while pulling the saw forward, accidentally comes in contact with the saw blade
2. the operator reaches for sawed stock while the machine coasts or idles, before the saw returns to normal "rest" position
3. an improperly adjusted saw swings beyond its safe limits into the body of the operator
4. the operator may be struck by the saw as it bounces forward from the idle position or as it swings or drifts forward when the spring or counterweight fails.

Hazard Control
Point of Operation Guard

OSHA regulations for swing cutoff saws apply also to sliding cutoff saws mounted above the table. Hoods are required in 29 CFR 1910.213:

> Each swing cutoff saw shall be provided with a hood that will completely enclose the upper half of the saw, the arbor end and the point of operation at all positions of the saw. The hood shall be constructed in such a manner and of such material that it will protect the operator from flying splinters and broken saw teeth. Its hood shall be so designed that it will automatically cover the lower portion of the blade, so that when the saw is returned to the back of the table, the hood will rise on top of the fence, and when the saw is moved forward, the hood will drop on top of and remain in contact with the table or material being cut.

At the end of the cut, the lip of the hood should be in contact with the table surface.

Special regulations apply to inverted swing cutoff saws:

> Inverted swing cutoff saws shall be provided with a hood that will cover the part of the saw that protrudes above the top of the table or above the material being cut. It shall automatically adjust itself to the thickness of and remain in contact with the material being cut.

Counterweight

OSHA also requires an automatic device to return the saw to the back of the table:

> Each swing cutoff saw shall be provided with an effective device to return the saw automatically to the back of the table when released at any point of its travel. Such a device shall not depend for its proper functioning upon any rope, cord or spring. If there is a counterweight, the bolts supporting the bar and counterweight shall be provided with cotter pins; and the counterweight shall be prevented from dropping by either a bolt passing through both the bar and counterweight, or a bolt put through the extreme end of the bar, or, where the counterweight does not encircle the bar, a safety chain attached to it.

Limit Chains

OSHA further requires:

> Limit chains or other equally effective devices shall be provided to prevent the saw from swinging beyond the front or back edges of the table or beyond a forward position where the gullets of the lowest saw teeth will rise above the table top.

Latch

A latch should be provided to catch and retain the saw at the rear of the table and to prevent it from rebounding. In some cases a nonrecoiling spring or bumper is adequate.

Saw Table

Each swing and sliding cutoff saw table can be provided with a wood bumper or a pipe guard to prevent bodily contact with the saw blade when it is extended the full length of the support arm.

Safe Operation

While operating the saw, it is important that the operator stand to the side of the saw on which the handle is located. The operator should use the hand nearest the handle. This keeps the operator's body out of line with the saw and makes it unnecessary to bring the hands near the saw while it is cutting.

Personal Protective Equipment

Proper personal protective equipment, such as goggles or a face shield, shall be worn by the operator.

Overhead Drives

If an overhead drive is used, the entire drive line should be enclosed.

Operating Controls

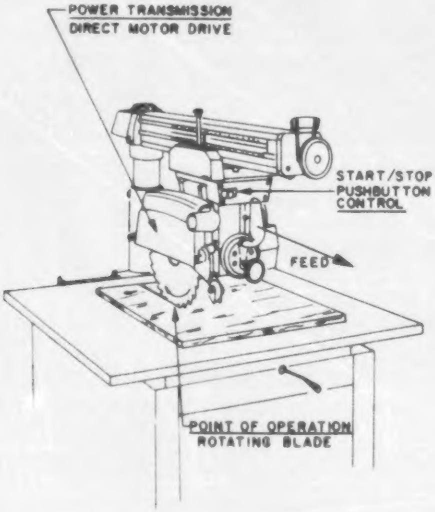
Operating controls should be recessed or shrouded, and an emergency stop switch is highly recommended. A main power electrical disconnect is necessary.

Exhaust System

An exhaust system is desirable.

RADIAL SAWS

Radial saws, developed from the old type of swing saw, are both versatile and dangerous. They cut downward and pull the wood away from the operator and against a fence (see Figure 46). Many adjustments are required to permit its full use, and these adjustments can create additional hazards.



CUT-OFF SAW

Sketch does not show floating guard. Adapted and reprinted from *Machine Guarding–Assessment of Need* (Cincinnati: NIOSH, 1975), p. 21.

Figure 46

Mechanical and Operational Hazards

The principal hazards are those common to other power-driven saws: cutting injuries caused by the saw blade and the injuries from flying materials and kickbacks.

Hazard Control
Point of Operation Guard

OSHA requires that the upper half of the saw be guarded and that the lower half have a floating guard:

> The upper hood shall completely enclose the upper portion of the blade down to a point that will include the end of the saw arbor. The upper hood shall be constructed in such a manner and of such material that it will protect the operator from flying splinters, broken saw teeth, etc., and will deflect sawdust away from the

> operator. The sides of the lower exposed portion of the blade shall be guarded to the full diameter of the blade by a device that will automatically adjust itself to the thickness of the stock and remain in contact with stock being cut to give maximum protection possible for the operation being performed.

Return Device

OSHA regulations further mandate that the unit be installed so that the front end of the unit is slightly higher than the rear. This will "cause the cutting head to return gently to the starting position when released by the operator" and prevent the cutting head from creeping toward the operator during crosscut operations. Furthermore,

Adjustable Stop

> An adjustable stop shall be provided to prevent the forward travel of the blade beyond the position necessary to complete the cut in repetitive operations.

Safe Operation

When the radial saw is used for crosscutting, the saw is pulled across the cutting area by a handle located on one side of the saw. For safe operations, the same stance should be assumed as was described in handling the swing cutoff saw.

When the radial saw is used for ripping, special precautions are necessary. A spreader must be provided, and OSHA requires:

Nonkickback Fingers

> Each radial saw used for ripping shall be provided with nonkickback fingers or dogs located on both sides of the saw so as to oppose the thrust or tendency of the saw to pick up the material or to throw it back toward the operator. They shall be designed to provide adequate holding power for all the thicknesses of material being cut.

Direction of Feed

Furthermore, the direction of the saw blade rotation must be upward toward the operator:

1-1/2" = 38 mm.
3/4" = 19 mm.

> Ripping and ploughing shall be against the direction in which the saw turns. The direction of the saw rotation shall be conspicuously marked on the hood. In addition, a permanent label not less than 1-1/2 inches by 3/4 inch shall be affixed to the rear of the guard at approximately the level of the arbor, reading as follows: 'Danger: Do Not Rip or Plough from This End.' Such a label should be colored standard danger red.

Personal Protective Equipment

When using a radial saw, students should wear safety glasses or face shields. As with other power saws, they should not wear gloves, rings, chains or loose clothing.

PORTABLE CIRCULAR SAWS

Guarding for portable circular saws is required by OSHA (29 CFR 1910.243):

> All portable, power-driven circular saws having a blade diameter greater than two inches shall be equipped with guards above and below the base plate or shoe. The upper guard shall cover the saw to the depth of the teeth, except for the minimum arc required to permit the base to be tilted for bevel cuts. The lower guard shall cover the saw to the depth of the teeth, except for the minimum arc required to allow proper retraction and contact with the work. When the tool is withdrawn from the work, the lower guard shall automatically and instantly return to covering position.

OSHA also requires that hand-held powered circular saws be equipped "with a constant pressure switch or control that will shut off the power when the pressure is released."

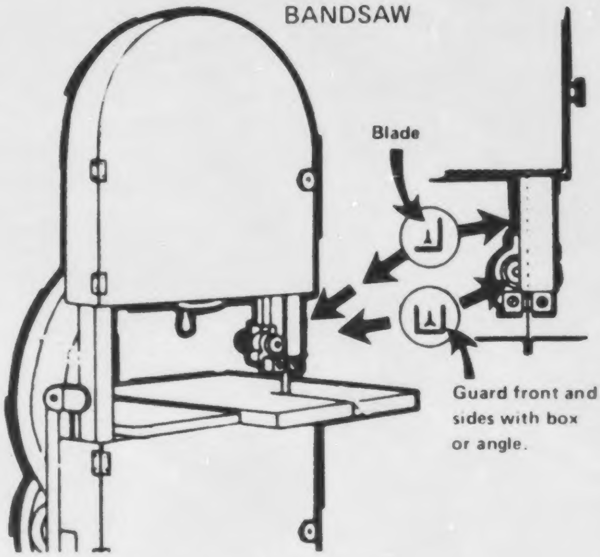
BANDSAWS

Up to this point we have been discussing kinds of circular saws. Now we come to the second category, the bandsaw. This is a machine which can be used for straight sawing as well as for cutting curved pieces. It uses a thin, flexible, continuous steel strip with cutting teeth on one edge. The blade runs on two pulleys through a work table, where stock is fed into it (see Figure 47).

Machine Guarding

OSHA regulations require the following safety devices for bandsaws and band resaws:

1. an enclosure or guard for all portions of the saw blade except for the working portion between the bottom of the guide rolls and the table
2. enclosure for wheels
3. effective brakes to stop the wheel in case of blade breakage (not required, but highly recommended)
4. a tension control device to indicate the proper tension for the standard saws used on the machine



Band or band resaw wheels MUST be completely enclosed and all portions of the blade MUST be guarded, except that portion between the guide rolls and the table.

Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 125.

Figure 47

5. a guard on the feed rolls of band resaws, to prevent the hands of the operator from coming in contact with the in-running rolls at any point.

Safe Operating Requirements

The American National Standards Safety Requirements for Woodworking Machinery (ANSI 01.1-1971), stress the importance of proper tension for the blade. Improper tension results in saw breakage. Other operating practices which this standard requires or recommends include:

Adjust Back Thrust

1. Back thrust shall be adjusted to the normal position of the saw blade.

Prevent Dust Accumulation

2. To secure satisfactory operation, means should be provided for preventing the accumulation of dust on the rim of the bandwheels.

Use a Proper Sized Blade

3. It is poor practice to use a small saw for large work or to force a wide saw to cut on a small radius. The saw blade

should in all cases be as large as the nature of the work will permit.

Do Not Stop Saw Quickly

4. Saws should not be stopped too quickly, or by thrusting a piece of wood against the cutting edge of the teeth when the power is off.

Avoid Vibration by Proper Thickness of Brazed Joints

5. To avoid vibration, brazed joints shall be the same thickness as the saw blade.

Examine Blades Regularly

6. Band saw blades shall be periodically examined to avoid use of cracked blades or blades which indicate probability of breakage.[6]

Other safe work practices include:

- setting the guard to just clear the stock to be cut
- if the stock being cut binds the blade, shutting off the machine and letting it stop before backing the work off the blade
- making release cuts before doing curves
- keeping the work area clean and clear of scraps
- using a brush to clean the saw table
- shutting off the machine and getting clear of it until it stops in the event of a blade breaking
- making all cuts when the power is on, never while the machine is coasting after power has been turned off.

JOINTERS

A jointer is an electric-power machine used for facing or flattening wood by passing the stock over a cylindrical multiple-knife cutter head. It does the work of a hand plane, and, when operated by an experienced person, it can do many other jobs.

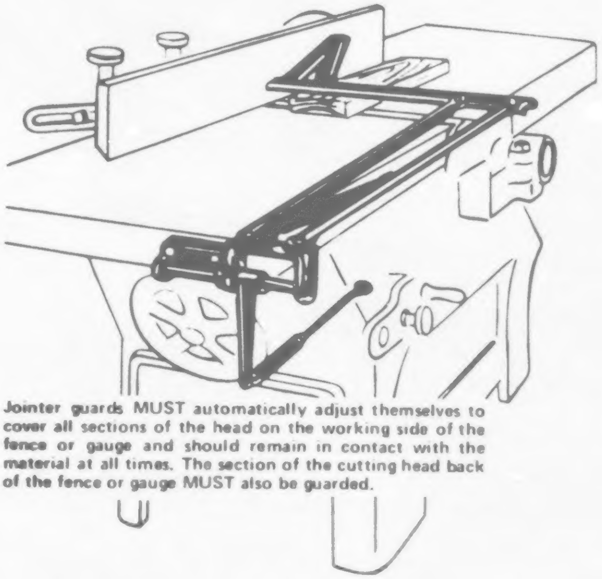
There are separate OSHA regulations for hand-fed jointers with horizontal cutting head and for wood jointers with vertical head.

Hand-Fed Jointers with Horizontal Cutting Head

For the first category, the following guarding requirements apply:

Each hand-fed planer and jointer with horizontal head

Point of Operation Guards



Jointer guards MUST automatically adjust themselves to cover all sections of the head on the working side of the fence or gauge and should remain in contact with the material at all times. The section of the cutting head back of the fence or gauge MUST also be guarded.

Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 127.

1/8" = 3 mm.

> shall be equipped with a cylindrical cutting head, the knife projection of which shall not exceed one-eighth inch beyond the cylindrical body of the head.
>
> The opening in the table shall be kept as small as possible. The clearance between the edge of the rear table and the cutter head shall be not more than one-eighth inch. The table throat opening shall be not more than 2-1/2 inches when tables are set or aligned with each other for zero cut.

2-1/2" = 64 mm.

The opening between the table and the head should be just large enough to clear the knife. Deeper cuts should be avoided. Not only do they require a larger table opening, but such cuts also create kickback hazards.

The regulation continues:

> Each hand-fed jointer with a horizontal cutting head shall have an automatic guard which will cover all the section of the head on the working side of the fence or gauge. The guard shall effectively keep the operator's

> hand from coming in contact with the revolving knives. The guard shall automatically adjust itself to cover the unused portion of the head and shall remain in contact with the material at all times.
>
> Each hand-fed jointer with horizontal cutting head shall have a guard which will cover the section of the head back of the gauge or fence.

Wood Jointers with Vertical Heads

Wood Jointers with vertical heads must have

> . . . either an exhaust hood or other guard so arranged as to enclose completely the revolving head, except for a slot of such width as may be necessary and convenient for the application of the material to be jointed.

Safe Operation

Jointers are second only to circular saws as the most dangerous woodworking machines. Since jointers are used primarily in the jointing of small pieces of material, many serious accidents are frequently caused when jigs or similar holding devices are not used when working with small size blades. The minimum length of the piece jointed should be not less than four times the width of the bed opening.

Push Sticks

Push sticks or blocks must be provided in the sizes and types suitable to the work being done. Use of push sticks prevents stock from tipping and also guards operators' fingers from coming in contact with knives.

Knives

Knives on jointers should be checked often for proper setting or adjustment, but knives or fence guards should never be adjusted unless the machine has come to a complete stop and the power has been turned off. Knives must be kept sharp.

Personal Protective Equipment

Housekeeping

Since a considerable amount of dust and chips is generated during the operation, the worker should be provided with proper and adequate personal protective equipment. A brush should be used to remove chips and dust from around knives or the area of the cutting head. Floors and the area around jointers should be kept free of debris which could cause stumbling or slipping.

Automatic Feed Device

An automatic feed device can be mounted above the stock, eliminating the need for the operator's hands to be near the cutter head.

Operating Controls

Operating controls should be recessed or shrouded. An emergency stop switch and a main power electrical disconnect are essential.

Exhaust System

An exhaust system is desirable.

Appropriate Clothing

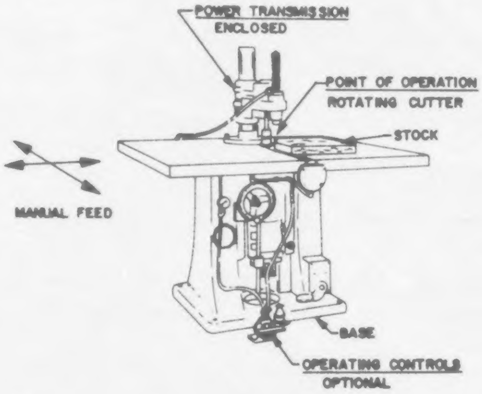
Neither gloves nor loose clothing should be worn by the operator or others working around jointers.

Guard Inspection

Guards should be inspected frequently. Operators must never make a guard inoperative for any purpose.

SHAPERS

The shaper (see Figure 48) is a woodworking machine with a variety of uses. Its most common use is shaping the edges of stock by placing the material in contact with a vertical cutter mounted on a spindle. The spindle rotates at high speed, from 7,000 to 10,000 RPM. There are also double-spindle machines.



Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 25.

Figure 48

Point of Operation Hazard

The shaper is one of the most difficult of all woodworking machines to guard effectively. Because of the designed use of this machine, guarding at the point of operation is difficult. Guards can be designed to be used when the machine is not being operated, but they are usually removed during operation to allow full manipulation of the stock. A self-adjusting guard that will minimize cutter exposure is necessary.

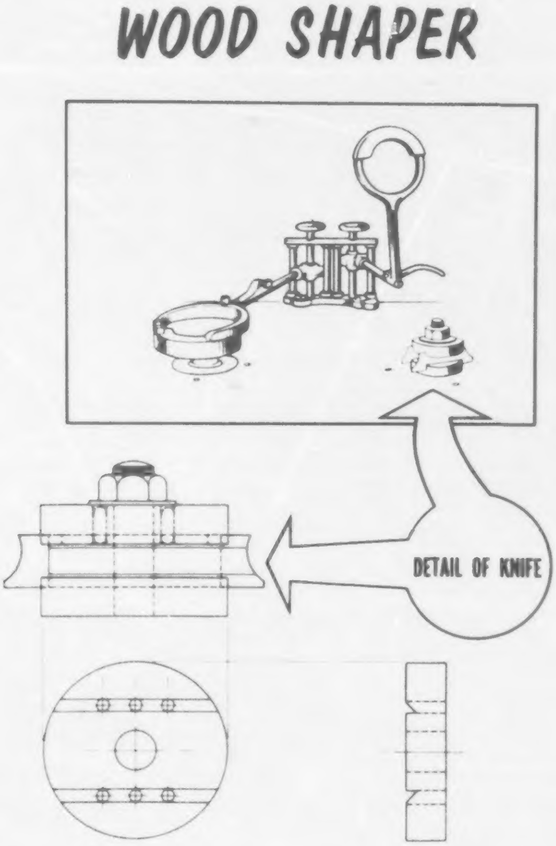
Point of Operation Guards

For each wood shaper which is not automatically fed, OSHA requires that the cutting head

> . . . shall be enclosed with a cage or adjustable guard so

> designed as to keep the operator's hands away from the cutting edge. The diameter of circular shaper guards shall be not less than the greatest diameter of the cutter. In no case shall a warning device made of leather or other material attached to the spindle be acceptable.

The following illustration shows ring guards which cover the top of the spindle and knives and which surround the knives just enough to clear the stock.



Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 30.

Knife Construction

Knives on shapers should be made from the best shaper steel available. Knives should be sharpened and kept in adjustment by qualified personnel. Both knife blades and collars for shaper heads should be precision ground so as to give uniform pressure on all knife blades and keep them from flying out while the machine is in motion. Knives should be balanced and should fit properly. The operator should be alert for chatter, which indicates that the knives are out of balance. Materials should always be fed into knives gradually, and at no time should cuts be heavy.

The American National Standard Safety Requirements for Woodworking Machinery (ANSI 01.1-1971) recommends that collars be provided with "stop-pins" and that knife blades have a recess cut in them for the pin. (Serrated collars and knives are an acceptable alternative.) This added precaution keeps blades from flying out.

Severe accidents are caused when broken knives are thrown by the machine. When a shaper knife breaks or is thrown from the collar, the other knife is usually thrown too, with the result that four or five heavy pieces of steel are thrown about the shop with sufficient speed to cause serious injury and even death.

Solid cutters which fit over the spindle are preferred to knives, which can be broken or thrown. The initial cost is greater for cutters than for knives, but in the long run cutters are less expensive. In all cases they are safer.

Power Transmission Guards

All belts, pulleys and drives should be completely enclosed by metal or mesh guards.

Exhaust System

Exhausts with adjustable hoods are considered a necessity. They help keep chips and dust from accumulating near cutter heads, reducing the need for manual cleaning of heads and surrounding floor area.

Personal Protective Equipment

The operator should be provided with proper and adequate personal protective equipment. Safety goggles are important, as are aprons made of metal mesh or leather reinforced with metal studs.

A brush instead of the hands should be used to clean chips and dust from around knives and cutting areas.

Safe Operation

Templates, jigs and fixtures which will remove the operators' hands from the point of operation should be used wherever possible. All clamping devices must be in good condition. The stock side of the device should be abrasive-lined for better grip.

OSHA recommends that cylindrical heads be used wherever the nature of the work permits.

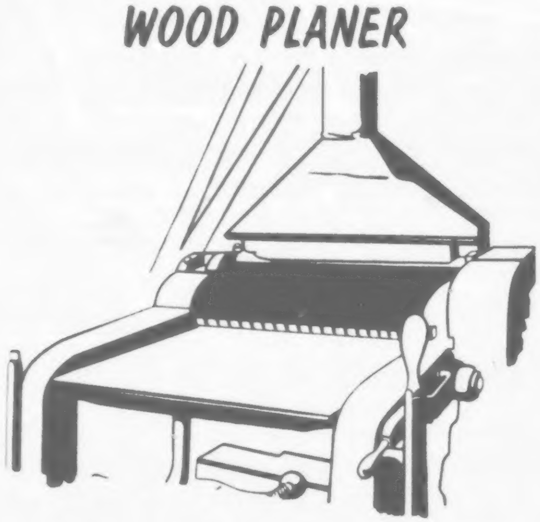
There should be some type of braking device to stop the spindle after the power is shut off. OSHA requires that "all double-spindle shapers shall be provided with a spindle starting and stopping device for each spindle."

Spindle tops should be detachable, self-centering and interchangeable. The spindle adjustment mechanisms should be kept in good operating condition. The hand wheel for spindle control should have a graduated setting, operate easily and be within convenient reach of the operator.

When feeding the shaper, the operator must remember that the direction of the cut must be made in the direction opposite to the rotation of the cutting head.

WOOD PLANERS

A wood planer, also called a thickness-planer or sufacer, is a woodworking machine designed to dress and size rough sawed lumber on one or more sides. It planes boards to an even thickness. Stock passes under or between cylindrical, multiple-knifed cutter heads (see Figure 49).



Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 22.

Figure 49

These surfacing machines are less hazardous than jointers and shapers because they are powerfed and the operator's hands need not come close to the cutting head. The planer operator simply has to adjust for cut and then feed the stock into the infeed side of the machine. He then retrieves the surfaced board from the outrunning end.

Mechanical and Operational Hazards and Controls

Hazards may be inherent in point of operation, kickbacks, flying particles, vibration or clearances.

Power Transmission

Planers are often driven from a line shaft comprised of belts and pulleys running on the back side of the planer. Planer parts driven by belts and pulleys, even though they may be on the back side of the planer, should be completely enclosed by sheet metal or heavy mesh guards. Guards should always be used regardless of the planer's location.

Point of Operation Hazard

Accidents at the point of operation arise from:

1. contact with blades while sharpening or adjusting
2. pinching fingers and hands between materials and in-running rolls which are inadequately guarded.

Point of Operation Guards

OSHA requires that planing machines "shall have all cutting heads, and saws if used, covered by a metal guard." This guard should be kept closed when the planer is running. Specific requirements apply to the material from which the guard is constructed:

1/16" = 2 mm.
3/16" = 5 mm.

> If such guard is constructed of sheet metal, the material used shall be not less than 1/16 inch in thickness, and if cast iron is used, it shall be not less than 3/16 inch in thickness.
>
> Where an exhaust system is used, the guards shall form parts or all of the exhaust hood.

Feed Roll Guards

OSHA regulations require feed roll guards:

> Feed rolls shall be guarded by a hood or a suitable guard to prevent the hands of the operator from coming in contact with the in-running rolls at any point. The guard shall be fastened to the frame carrying the rolls so as to remain in adjustment for any thickness of stock.

The student must be sure that feed rolls, cutter heads and cylinders are stopped before reaching into the bed plate to remove wood fragments or to make adjustments. Sleeves must be tucked in or rolled up, and loose clothing should not be worn. Although gloves should not be worn while operating a planer, hand pads for handling rough wood may be necessary.

Kickbacks

Kickbacks or throwing material toward the operator through action of the blade can be caused by:

1. unsafe operating methods

2. improper equipment maintenance or adjustment

3. lack of physical safeguards.

Kickback Protection

Kickbacks cannot be prevented entirely by mechanical means. Therefore, the operator should always stand out of line of board travel. OSHA regulations require:

> Surfacers or planers used in thicknessing multiple pieces of material simultaneously shall be provided with sectional infeed rolls having sufficient yield in the construction of the sections to provide feeding contact pressure on the stock, over the permissible range of variation in stock thickness specified or for which the material is designed. In lieu of such yielding sectional rolls, suitable section kickback finger devices shall be provided at the infeed end.

Operators should never feed boards of different thickness at the same time because the thinner board will not be held by the feed rolls and can be kicked back from the cutter heads. Feed roll corrugations should be kept clean and free from dust, pitch, or any other impediments. They should be kept sharp by filing as needed so that they grip the material as tightly as possible.

Flying Particles

Chips, splinters, etc., are thrown off as a result of the rapid cutting action of the blade. The operator should wear a face shield or goggles as protection against slivers and chips thrown back by the cutter heads. He should not bend over to watch the board being planed but should stand aside once the board starts through. A dust collection system is desirable to reduce the hazard of flying particles.

Vibration

A planer is powerful, fast running and tends to vibrate excessively. Vibration also may be caused by dull or improperly sharpened blades. Vibration can be reduced by anchoring the planer on a solid foundation and, if necessary, by insulating it from the foundation with materials that absorb vibration.

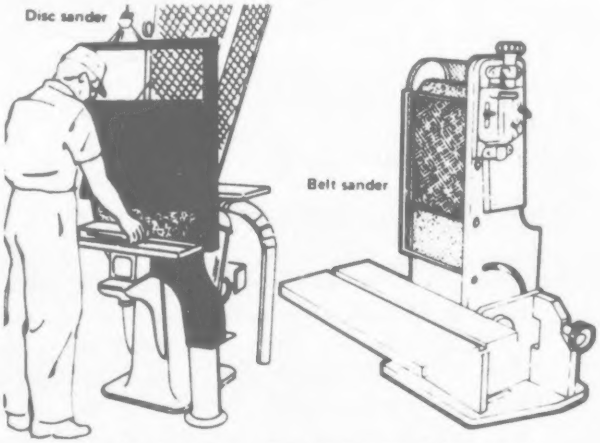
The planer is a noisy machine. Therefore, it should be isolated or enclosed in a soundproof area. If neither of these alternatives is possible, those working the the immediate area will need ear protection.

Since materials passing through the planer are generally long and fast-moving, workers can be caught between stock emerging from the planer and stationary objects or structural elements of the building. The space at the outrunning end should be fenced or marked off to keep workers out of the area. Insofar as possible, aisles should be located where students will not need to pass in front of or to the rear of the planer.

SANDING MACHINES

Three major types of machines are commonly used to sand surfaces:

1. drum sanders
2. disk sanders
3. belt sanders (see Figure 50).



Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 132.

Figure 50

Point of Operation Hazard and Control

Accidents at the point of operation may occur when operators' hands or fingers become caught between the work rest and the belt on a manually fed machine, between the feed rolls and the material on a self-feed machine or by accidental contact with the moving abrasive belt.

Self-Feed

Because of the dangers presented to hands and fingers at the point of operation, OSHA requires machine guarding:

> Feed rolls of self-feed sanding machines shall be protected with a semicylindrical guard to prevent the hands of the operator from coming in contact with the inrunning rolls at any point. The guard shall be constructed of heavy material, preferably metal, and firmly secured to the frame carrying the rolls so as to remain in adjustment for any thickness of stock. The bottom of the guard should come down to within 3/8 inch of a plane formed by the bottom or contact face of the feed roll where it touches the stock.

3/8" = 10 mm.

Hand-Fed

All manually-fed sanders should be equipped with a work rest and be properly adjusted:

1. to provide minimum clearance between the belt and the rest
2. to secure support for the work being sanded.

Pieces too small to allow the hands to be kept a safe distance from the work should be held in a jig or similar holding device.

Drum and Disk

The regulations for drum and disk sanders require an exhaust hood or, if no exhaust system is required, another guard arranged to enclose the revolving drum or disk, except for the portion above the table designed for the work feed. The distance between disk or drum and the table must be kept to a minimum.

Belt

Belt sanding machines require more guards because of the additional hazard created by nip points:

> Belt sanding machines shall be provided with guards at each nip point where the sanding belt runs on to a pulley. These guards shall effectively prevent the hands or fingers of the operator from coming in contact with the nip points. The unused run of the sanding belt shall be guarded against accidental contact.

Dust and Flying Particles

Considerable dust and bits of wood are thrown off in the sanding process. Eye protection is highly recommended.

Exhaust Systems

Sanders should be provided with an exhaust system. The exhaust hood should cover all the sanding surface except the operating area. Exhaust intakes should be designed and placed so that the natural throw of the abrasive belt is directly into the exhaust hood. Intakes should be placed as near as possible to the point of contact of the wood with the abrasive belt. Personnel operating sanders should wear goggles and dust-type respirators during sanding operation and while cleaning up afterwards.

Loose Belts

Loose or improperly tensioned belts cause undue wear and fraying and can tear or break, causing material on the jam or belt to fly toward the operator.

Belt Maintenance

Abrasive belts used on sanders should be the same width as the pulley-drum, and drums should be adjusted to keep the abrasive belt taut enough to turn at the same speed as the pulley-drum, yet not slip on the drum when material is brought into contact with the moving abrasive belt. Abrasive belts should be inspected before use, and those found to be cracked, frayed or excessively worn in spots should be replaced, even though the remainder of the belt appears to be in good condition.

Operating Controls

The operating controls, while not a severe source of injury, should include an emergency stop button. A main power electrical disconnect is required.

MAINTAINING WOODWORKING MACHINERY

In the section on machinery and machine guarding, OSHA established nine inspection and maintenance requirements for woodworking machinery:

1. Dull, badly set, improperly filled or improperly tensioned saws shall be immediately removed from service, before they begin to cause the material to stick, jam or kick back when it is fed to the saw at normal speed. Saws to which gum has adhered on the sides shall be immediately cleaned.

2. All knives and cutting heads of woodworking machines shall be kept sharp, properly adjusted and firmly secured. Where two or more knives are used in one head, they shall be properly balanced.

3. Bearings shall be kept free from lost motion and shall be well lubricated.
4. Arbors of all circular saws shall be free from play.
5. Sharpening or tensioning of saw blades or cutters shall be done only by persons of demonstrated skill in this kind of work.
6. Emphasis is placed upon the importance of maintaining cleanliness around woodworking machinery, particularly as regards the effective functioning of guards and the prevention of fire hazards in switch enclosures, bearings and motors.
7. All cracked saws shall be removed from service.
8. The practice of inserting wedges between the saw disk and the collar to form what is commonly known as a "wobble saw" shall not be permitted.
9. Push sticks or push blocks shall be provided at the work place in the several sizes and types suitable for the work to be done.

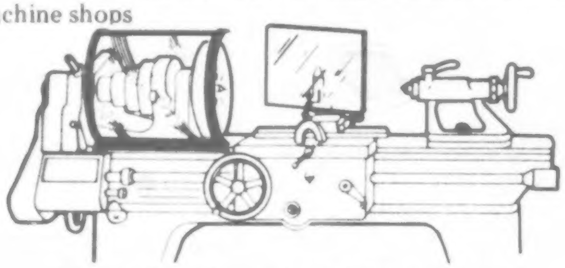
METAL LATHES

The common characteristic of lathes is that a piece rotates about a horizontal axis and is shaped by a tool. Metal lathes are used for cutting or shaping metal by removing chips from the workpiece. As the piece revolves, the tool feeds into it or across it. Boring is sometimes done on a lathe; however, the holes are usually larger than those made on a regular boring or drilling machine.

The metal lathe is the tool in the machine shop which the beginner usually learns to operate first. There are two main types:

Engine Lathe

1. *the engine lathe* (which includes the ordinary bench lathe), the regular revolving or turning lathe found in most machine shops



Adapted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 133.

Turret Lathe

2. *the turret lathe,* where a number of tools are fixed in a monitor or turret, pivoted so as to revolve and present any of the various tools to the work. In many automatic lathes and screw-machines, the motions of the work and the turret are directed by a cam wheel. The finished pieces are dropped out continuously at one end, while a bar from which the pieces are formed is fed at the other end.

Mechanical and Operational Hazards and Control

Lathes may be driven by individual motors or from a line shaft, comprised of belts and pulleys, or by exposed gears in the headstock. All belts, pulleys, shafting, gears, etc., should be guarded.

Power Transmission Push Sticks

Where power transmission belt drives are exposed to allow speed changes, a push stick or similar device must be available and used. Where the power transmission is enclosed, the access doors should be adequately latched so that they cannot jar open.

Moving Parts

Accidents occur in the moving parts through:

1. contact with projection on stock, faceplates and chucks
2. contacting lathe dogs (especially those with projecting set screws)
3. filing with the right hand, especially near dog or chuck, or using the hand instead of a stick to hold emery cloth against the work
4. catching loose clothing or rags on rotating parts.

A guard should be provided for the faceplate and chuck to protect the operator from accidental contact with them. Enclosure guards over the chuck confine hot metal chips and oil splashes and also act as exhaust hoods for removal of fumes.

If possible, faceplates and chucks should be without projections. Safety lathe dogs should be substituted for those with projecting setscrews. All filing should be done with the left hand, and the file should be kept away from the chuck and lathe dog.

Safe Clothing

Lathe operators should not wear gloves, neckties, loose clothing, long sleeves, or wrist watches, chains, rings, etc., while operating the lathe. Gloves worn because of the hazards of burrs or sharp edges should be taken off before starting the lathe.

Point of Operation

Accidents occur at the point of operation through:

1. calipering or gauging the job while the machine is in operation
2. accidental contact with the tool
3. attempting to clean chips while machine is in operation
4. contacting projections on work or stock
5. hand braking of the machine.

Care should be taken to remove chuck keys from the chuck sockets before the lathe is started.

Center holes of taper work should be clean and true, and lathe centers true and sharp. The work should be well countersunk at the tailstock end to eliminate any danger of its being torn loose.

Automatic machines should have point-of-operation enclosures interlocked with the control circuit. These enclosures should open easily for access to the work and tooling.

Operating Controls

Operating controls, where possible, should be protected against accidental starting by shrouding push buttons and by identifying levers and hand controls with bright colors. Every lathe should have an emergency disconnect switch in the proximity of the operator.

Flying Particles

On some types of metals, a continuous spiral is produced which frequently causes injuries to the hands, arms or face. Small particles are also thrown off, which create a hazard to the eyes of the operator and to others in the vicinity.

A small mesh screen or plastic chip guard should be provided which will protect the operator from flying chips. Such a guard confines the chips and does not interfere with visibility.

Always wear goggles or face shields for protection against flying chips and oil spatters.

Continuous spiral chips should be removed with a hooked rod, never with the hand. Small chips should be removed with a brush. Remove chips only after the lathe has completely stopped.

Chip breakers provide protection from the hand and arm injuries caused by continuous spirals of such materials as steel. Chip breakers may be ground into the tip of the tool, or they may be clamped or brazed onto the tool.

Housekeeping

The floor and aisle area should be kept clear. All tools, extra work, stock and so forth should be placed in a suitable rack. A lifting device should be provided for changing chucks, faceplates, etc.

Operators should wash thoroughly and wear clothes free of oil. Operators should wear a hat or cap while working.

Safe Operation

Other safe operating requirements include the following. Before turning on power:

1. Properly clamp tool holder, tailstock and work.
2. If a magnetic chuck is used, turn on current before starting machine.
3. Be sure that automatic feeds are not overly tight.
4. Be sure that the compound rest or carriage cannot strike the chuck jaws.
5. Be sure that the jaws of a chuck do not extend beyond its circumference. Reverse or change jaws if necessary.
6. Set tool at proper height.
7. Enclose projecting material.

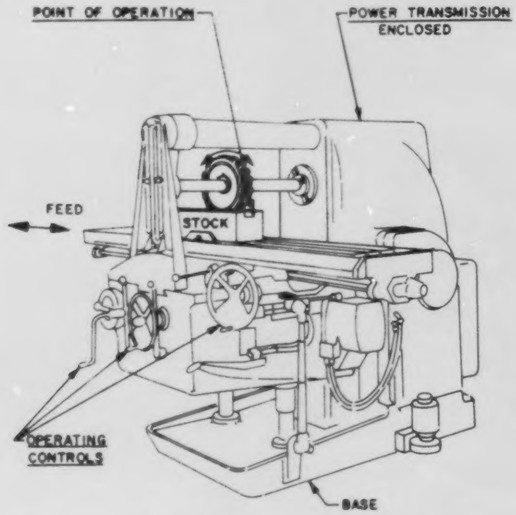
While operating the machine:

1. Avoid taking too heavy a cut.

2. Do not bend over the machine.
3. Do not shift gears.
4. Do not attempt to use a wrench.
5. Use only files equipped with handles.

MILLING MACHINES

Milling is the process by which a piece of metal is machined by bringing it into contact with a rotating multiple-edged cutter. The horizontal milling machine has the spindle horizontal to the table; the work is fed into the cutter (see Figure 51). The vertical milling machine has the spindle vertical to the table; stock can be fed to the tool or the tool can be fed to the stock (see Figure 52). The plain machine is used with tables that cannot swivel; the universal machine is used with tables that can swivel up to 90 degrees of a horizontal position.



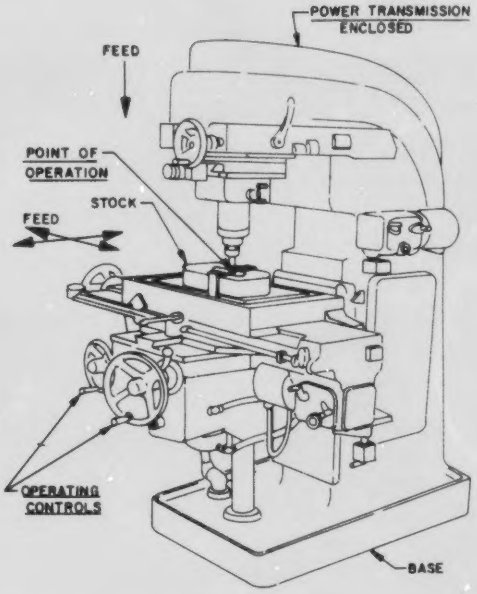
Sketch does not show guard.
Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 54.

Figure 51

Mechanical and Operational Hazards and Controls

Power Transmissions

Milling machines may be driven by individual motors or from a line-shaft, comprised of a belt and pulleys. Power transmission components should be totally enclosed. On those machines using adjustable belt drives, an interlock arrangement is required.



VERTICAL MILLING MACHINE

Sketch does not show guard.
Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 55.

Figure 52

Point of Operation

About two out of every three milling machine accidents occur at the point of operation when operators unload or make adjustments. There should be a fixed hood over the cutter or cutters clamped firmly to the overhead arm and adjustable to the work being done. A self-closing guard encloses the cutter completely when the table is withdrawn and opens automatically as the table moves forward. This should effectively protect the operator against accidental contact with the cutters and against flying chips and fragments.

Operating Controls

Operating controls should be shrouded, operating levels brightly identified, and an emergency safety switch installed. A main power disconnect is essential.

Auxiliary Devices

Auxiliary devices should have a proper storage place near the machine. These devices (index heads, stock vises, extra tooling) must be handled carefully.

Other point-of-operation controls include:

1. drawing the job back to a safe distance when loading and unloading
2. making sure that the jig or vise does not prevent close adjustment of the guard
3. being certain that the jig or vise-locking arrangement is not so placed that force must be exerted toward the cutter
4. clamping the work securely before starting the machine
5. using cutters which are dressed correctly
6. being certain that cutters are not exposed after the job has been withdrawn.

Safe Operating Practices

The horizontal milling machine should have a splash guard and pans for catching thrown cutting lubricant and lubricant running from the tools. Excess oil should not be cleaned from the table while the cutter is turning.

A coolant should be applied to the part of the tool which is turning away from the work. The coolant flow should be adjusted only when the cutters are not turning.

Chips should be removed with a brush, never with the hand, and then only when the milling machine is stopped.

Snug clothing should be worn when operating milling machines. The wearing of loose clothing, long sleeves, wrist watches, rings, etc., should be prohibited.

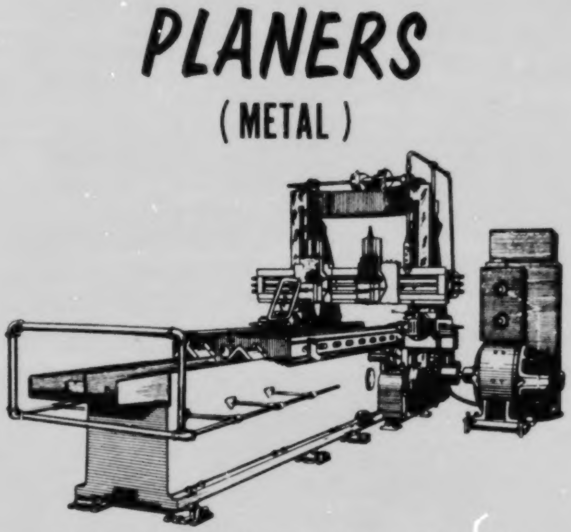
Milling machine operators should wash thoroughly to prevent possible dermatitis and infections from lubricants.

All guards should be in place while the machine is running. Operators should wear face shields or safety goggles to protect their eyes from chips and flying objects.

The machine should be stopped before measuring or calipering the work.

METAL PLANERS AND SHAPERS

Planers machine a metal surface with the cutting tool held stationary while the work moves back and forth underneath it (see Figure 53). Shapers are also generally considered planing machines. However, they reverse the process: the work is held stationary while the cutting tool is moved back and forth.



Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 37.

Figure 53

Like many other machine shop power tools, the metal planer is not dangerous to operate if certain safeguards are installed and if the operator is experienced and careful to follow closely safety rules and operating procedures. Most planer accidents are the result of unsafe practices.

Mechanical and Operational Hazards and Controls

Power Transmission

Planers may be driven by individual motors or from a lineshaft, comprised of a belt and pulleys. Accidents occur through contact with the counterweight and exposed power gears or through contact with reversing dogs.

All belts, pulleys, shafting, gears, etc., should be guarded. Counterweights should be guarded from the floor, extending upward throughout the travel of the counterweight. The reversing dogs on planers and shapers should be covered.

An emergency stop button and a main power electrical disconnect are required.

Point of Operation

Accidents occur at the point of operation through contact with the tool and through the breaking of a tool or gouging of the work caused by the shifting of the cutting tool which cuts into the work.

The tool should be set so that, if it shifts, it will raise away from the cut and will not dig into the work.

All work should be clamped properly and securely before the planer is started. When magnetic chucks are used, the work should be set in its proper position and the current turned on before the planer is started. A chip guard of heavy close-mesh wire screen or of heavy clear plastic material should be placed over the tool to prevent chips from flying and striking the operator or other workers.

Moving Parts Guards

All openings in the bed of planers should be covered with a permanent covering of solid heavy sheet metal to prevent a person from being caught between the bed and the planer table and to prevent the space from being used for the storage of tools and other articles.

If the planer table itself or materials being processed on it travels to within 18 inches of a post, wall or other obstruction, the space between the end of the travel and the obstruction should be protected by a standard railing on either side of the planer. Safety dogs should be placed at each end of the planer table to prevent it from running off the gear rack.

Safe Operation

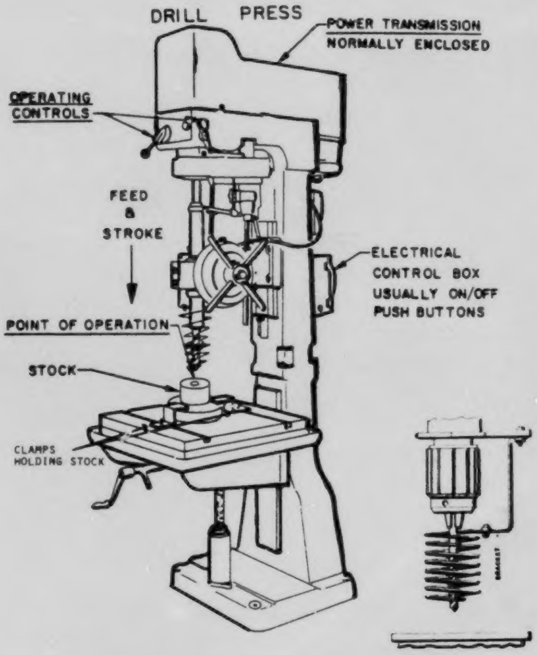
Several additional requirements for the safe operation of milling machines are:

1. Before starting a planer or shaper, check the condition of the machine and its setup. Be sure all guards are in place.
2. If any adjustments, repairs or measurements are necessary, stop the machine to make them.
3. Use a brush to remove chips.
4. Keep floor area clear.
5. Do not leave tools under the "bed."
6. Wear goggles to protect the eyes from flying chips and particles.

7. Wear snugly fitted clothes, short sleeves and no jewelry.
8. Do not leave the planer running unattended.
9. Do not place hands or fingers between the tool and the work.

DRILL PRESSES

The drill press is a metalcutting machine which uses a multiple-cutting-edge rotating tool to remove metal and produce a hole in the stock. It also can be used for countersinking, reaming, boring, tapping, facing and routing. The most commonly used drilling machine is a single-speed, floor-mounted, belt-driven machine for non-production drilling (see Figure 54).


DRILL PRESS
POWER TRANSMISSION NORMALLY ENCLOSED
OPERATING CONTROLS
FEED & STROKE
ELECTRICAL CONTROL BOX USUALLY ON/OFF PUSH BUTTONS
POINT OF OPERATION
STOCK
CLAMPS HOLDING STOCK

Drill press adapted from *Machine Guarding–Assessment of Need* (Cincinnati: NIOSH, 1975), p. 51. Safety mechanism reprinted from with permission from *Guards Illustrated,* 3rd ed. (Chicago: National Safety Council, 1973), p. 32.

Figure 54

There are three main types of drill presses:

1. upright (vertical spindle)

2. multiple spindle
3. radial, with a long arm which can be swung into any position around the column.

Mechanical and Operational Hazards and Controls

Drill presses may be driven by individual motors or from a lineshaft, comprised of belts and pulleys. There are also the hazards of gears, spindles and counterweights. Power transmission components should be entirely enclosed on those machines that have adjustable belt drives. The enclosure should have an interlocked access door to facilitate speed changes.

Counterweights

Counterweights should be enclosed with guards, preferably iron pipe or sheet metal and angle iron, from the floor to the top of the weight when in extreme upward position. Counterweight chains should be maintained in good condition.

Emergency Stop

An emergency stopping device should be provided within easy reach of the operator. (On motor-driven drills, stop-and-start buttons are acceptable.) A main power disconnect is necessary.

Point of Operation

Hazards at the point of operation include:

1. coming in contact with the spindle or tool
2. work slipping or turning because it was not properly clamped
3. attempting to clean chips while drill is turning
4. being hit by flying pieces from metal chips or a broken drill.

Where practical, a telescope guard should be installed over the drill and spindle to protect against accidental contact. Figure 54 shows a spring safety guard which compresses as the drill cuts in order to contain metal slivers and chips.

Safe Operation

All work should be firmly and securely clamped to the table before starting the drill press. Do not touch the tool while using a quick-change clutch.

A brush or stick should be used to remove chips from a drill. Burrs should be filed or scraped from drill holes, but this should be done only when the drill is stopped.

When deep holes are being drilled beyond the flutes of the drill, the drill should be removed frequently and the chips cleaned out with a brush or stick. If chips are allowed to pile up in such an operation, the tool may jam, causing the drill to break and insecurely clamped work to spin.

The drill should not be operated at excessive speed or feed; it may break or shatter. Do not use a dull drill.

Chuck wrenches, keys or drifts should not be left in chucks or on the table. All tools and loose material should be removed from the table before starting the machine.

When starting the drill, the operator should use a center punch mark. So that he does not drill into the table, he should position the work over an opening in the table or use a bottom piece under the work. To remove a drill bit from the chuck, the operator should lower the spindle so that the point of the drill is close to the table before loosening the socket.

The machine must be shut off before work is set up or taken off. Operators should shut off power and be certain the machine has stopped before leaving.

Control of Operational Hazards

Goggles should be worn when operating drill presses. Operators of the drill press should wear snugly fitted clothing, short sleeves, and no jewelry. Long hair should be confined in a proper hair net, hood or cap.

POWER PRESSES

Power presses are used to cold form a sheet of metal. A powered slide or ram moves in a reciprocating motion at right angles to a stationary bed. Mated dies are attached to the slide and the stationary bed. The slide applies tremendous pressure to close the dies, which cut or form the material placed between them.

The action of closing the dies creates particular hazards for the operator.

As a source of accidents, particularly those accidents which result in permanent-partial injuries, presses present possibly the most serious problem of any stationary machine in industry.

The safeguarding of presses has been complicated by the wide variety of operations and operating conditions, owing to the variations in size, speed, and the type of press; size, thickness and kind of pieces to be worked; design and construction of dies; required accuracy of the finished work; skill of operators; and length of the run.

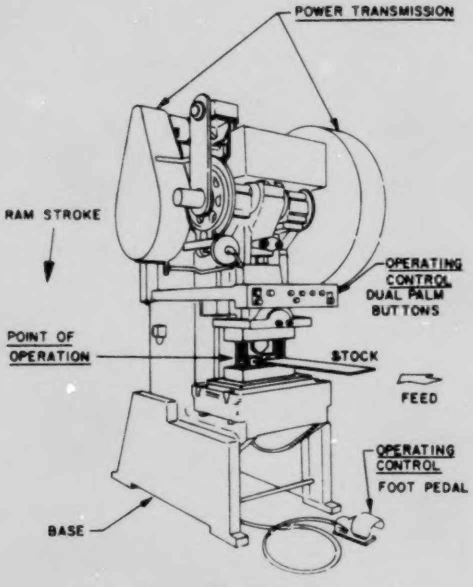
The four most common types of power presses are:

1. mechanical power press
2. hydraulic power press
3. power brake press
4. shear.

All power presses have counterparts which are powered by hand or foot. Such presses are easy to guard inexpensively.

MECHANICAL POWER PRESSES

The mechanical power press shears, punches, forms or assembles metal or other material by means of tools or dies attached to slides (see Figure 55). Most mechanical power presses are activated


POWER TRANSMISSION
RAM STROKE
OPERATING CONTROL
DUAL PALM BUTTONS
POINT OF OPERATION
STOCK
FEED
OPERATING CONTROL
FOOT PEDAL
BASE

MECHANICAL POWER PRESS

Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 40.

Figure 55

by a clutch and brake arrangement which engages the crankshaft to the heavy flywheel and thus cycles the press. If the clutch cannot be disengaged during the cycle, it is known as a full revolution clutch. If it can be disengaged at any point during the cycle, it is known as a part revolution clutch. Hydraulic and pneumatic-powered presses have the same operating characteristics as the part revolution clutch press.

Mechanical and Operational Hazards

The mechanical power press presents more hazards than any other piece of equipment because of its use in high production manufacturing, the nature of its metal working stroke and the need for integral operator involvement.

Applicable Standards

The American National Standards Institute has addressed itself to the safety problem in its ANSI B11.1-1971, Safety Requirements for Construction, Care and Use of Mechanical Power Presses. The policies included in this standard were made part of OSHA regulations (1910.217) in 1972.

The following discussion focuses on the hazards involved in total manual operation. Automation of any portion of the operation will reduce the hazard level.

Hazardous Point of Operation

Slipping Hazards

Sharp Edges
Machine Repeat
Broken Machine Parts
Operator Fatigue
Insufficient Training

The operator must work in close proximity to the top die/ram to allow proper placement of stock in the work zone. Often he is working at an accelerated pace, placing his hands between the dies on the up stroke and pulling them out on the down stroke. Often the workplace is slippery, creating a slipping hazard. Heavy material-moving equipment is in the immediate vicinity to deliver and take away stock. The material being handled may have sharp edges and elevated temperatures. The machine can repeat unintentially, creating a very dangerous hazard. Broken machine parts can come loose and fall on the operator. Operator fatigue can be present as well as insufficient training.

Power Transmission

The power transmission device is generally high enough above the operator to eliminate a hazard. However, on smaller presses, open gears, belt drives and clutch mechanisms create hazards. There may be oil and grease leakage from the transmission units, resulting in slippery walking surfaces. All belts, pulleys, gears, flywheels, etc., must be guarded; any counterweights and cables must be enclosed with a guard extending to at least seven feet from the floor.

Operating Controls

Operating controls are usually mounted near the work area. OSHA requires that the motor start button be protected against accidental operation. An emergency stop button and a main power disconnect switch are required with every power press control system. This disconnect switch must be capable of being locked only in the "off" position.

The operating controls must be shrouded and require two-handed operation or a foot switch. If a foot switch is used, OSHA requires that it "shall be protected to prevent unintended operation from falling or moving objects or by accidental stepping onto the pedal."

Antirepeat

OSHA also requires that two-hand controls incorporate an antirepeat feature and that clutch/brake controls "incorporate an automatic means to prevent initiation or continued activation of the Single Stroke or Continuous functions unless the press drive motor is energized and in the forward direction."

Braking

Effective braking is required:

> Friction brakes provided for stopping or holding a slide movement shall be inherently self-engaging by requiring power or force from an external source to cause disengagement. Brake capacity shall be sufficient to stop the motion of the slide quickly and capable of holding the slide and its attachments at any point in its travel.

Broken Parts

Because of the danger presented by broken machine parts, OSHA requires:

> Machine components shall be designed, secured or covered to minimize hazards caused by breakage, or loosening and falling or release of mechanical energy (i.e., broken springs).

Point of Operation Guards

A careful study should be made of the specific operating hazards on a particular job on a specific press. The safest quards should be installed to eliminate the hazard, and they should be maintained on a regular schedule.

Guards must be so designed and constructed that they completely protect the operator at the point of operation.

OSHA regulations state:

> It shall be the responsibility of the employer to provide

> and insure the usage of 'point of operation guards' or properly applied and adjusted point of operation devices on every operation performed on a mechanical power press.

Inspection

OSHA further requires periodic and regular inspections of power presses to ensure that "all their parts, auxiliary equipment and safeguards are in a safe operating condition." The regulation continues:

> Each press shall be inspected and tested no less than weekly to determine the condition of the clutch/brake mechanism, antirepeat feature and single stroke mechanism. Necessary maintenance or repair or both shall be performed and completed before the press is operated. The employer shall maintain records of these inspections and maintenance work performed.

Modification

Any modification made in the power press must be accompanied, according to OSHA, by instructions "to establish new or changed guidelines for use and care of the power press so modified."

Repairs and Adjustments

All repairs and adjustments must be made by a competent, authorized person. According to OSHA:

> It shall be the responsibility of the employer to insure the original and continuing competence of personnel caring for, inspecting and maintaining power presses.

Instruction and Supervision

Before the student begins work on the power press, he must be properly trained and instructed. OSHA requirements are:

> The employer shall train and instruct the operator in the safe method of work before starting work on any operation covered in this section. The employer shall insure by adequate supervision that correct operating procedures are being followed.

"No Hands in Dies" Policy

OSHA regulations enforce the "no hands in dies" policy which long has been advocated by the National Safety Council. The regulations require the employer to:

1. use dies and operating methods designed to control or eliminate hazards to operating personnel

2. furnish and enforce the use of hand tools for freeing and removing stuck work or scrap pieces from the die, so that no employee need reach into the point of operation for such purposes.

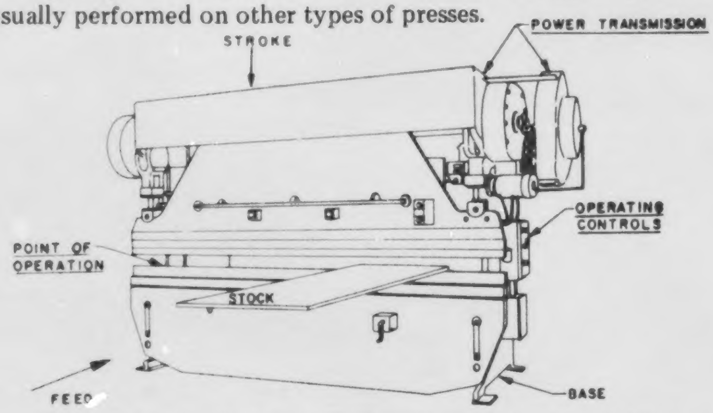
Furthermore, the employer must "provide and enforce the use of safety blocks for use whenever dies are being adjusted or repaired in the press." "Brushes, swabs, lubricating rolls and automatic or manual pressure guns" must be provided so that operators "shall not be required to reach into the point of operation or other hazard areas to lubricate material, punches or dies."

All mechanical power presses use some type of die in their points of operation. The die, which may weigh from a few pounds to several tons, must be changed, adjusted or repaired periodically. Many dies have razor-sharp edges both inside and out. If they are dropped, not only may they be damaged but any part of the body they contact will suffer.

When dies require mechanical handling, handling equipment attach points must be provided. Safety blocks are required "whenever dies are being adjusted or repaired in the press" and die stops must be provided "to prevent losing control of the die while setting or removing dies in presses which are inclined."

BRAKE PRESSES

The brake press is also called the "press brake," bending brake," "power brake" and "bending press' (see Figure 56). Its primary function is forming (cold) channels, angles, etc., in metal plates, strips and in sheet metal. It is used less frequently for punching, corrugating, notching, trimming, embossing and other operations usually performed on other types of presses.



Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 53.

Figure 56

Like mechanical and hydraulic power presses, the brake press has a bed and a descending slide, called the ram. Its distinguishing feature is the die space. The bed and ram are long left-to-right, with narrow front-to-back standard die-attachment surfaces. The press brake can be powered either mechanically or hydraulically. Both types utilize the part revolution clutch type of drive and thus can be started and stopped at will.

Most of the safety requirements for mechanical power presses can be applied to brake presses as well. ANSI B11.3-1973 is the American National Standard which contains safety requirements for the construction, care and use of power brake presses.

Mechanical and Operational Hazards and Controls

Power Transmission

Hazards occur at the power transmission point through contact with power pulleys, gears, chains, cranks, couplings and other moving parts exposed to contact. All such moving parts should be guarded with either complete enclosures of sheet metal or standard guards to a height of at least seven feet from the floor or working platform.

Point of Operation

Hazards at the point of operation include fingers or hands being crushed between the punch and the die or between the work and the ram, and cuts from contact with work being processed.

When narrow stock is being worked, the hands of the operator are very near the path followed by the ram. To reduce this hazard, the machine should be equipped with mechanical safeguards which are maintained in good working order.

The press should be provided with starting devices which will keep the hands of the operator out of the danger zone. These may include two-hand switches or levers and treadle bars, foot pedals and foot switches.

Foot Controls

Press brakes should be provided with foot controls for use on those jobs where the size of the stock being processed requires an operator to hold it in position. Before the ram is driven home, the two-hand buttons or levers should be used to bring the die into position, allowing minimum clearance. The stock is then centered and formed by the further action of the ram, which is actuated by the operator depressing the foot controls.

Foot controls must have a pad large enough to allow even distribution of the actuating pressure applied by the operator's foot. The pad must be firmly attached to the pedal and have a non-slip contact area. The foot pedal itself must be removable and capable of being adjusted to left or right so that the operator can activate it at a location to suit his work. A means must be provided to prevent any accidental activation of the foot controls.

The operator should know the capacity of the machine and the three factors which determine the brake pressure required to form the material to be worked to a 90 degree bend:

- length of work
- thickness of work
- sharpness of the bend.

Safe Operation

Before the press action is started, it should be positively determined that there is adequate clearance for changing the shape of the stock being worked and that work stops or back gates are at the proper height. All parts of the control mechanisms should be inspected at regular intervals. The functioning of friction clutch and brake needs to be checked; the clutch must disengage itself when the external engaging force has been removed.

All replacement parts should be purchased from the manufacturer, and his recommendations for the operation and maintenance of the machine should be followed.

POWER SHEARS

The fourth of the cold forming metal presses is the power shears (see Figure 57). Shearing metal is its sole purpose. It is available with either full or part revolution clutch/brake drives as a mechanical shear; it may also have hydraulic or pneumatic drive. The operator feeds the stock between the blades, sees that it is properly positioned, activates the cutting cycle with hand/foot controls and removes the completed part.

Applicable Standard

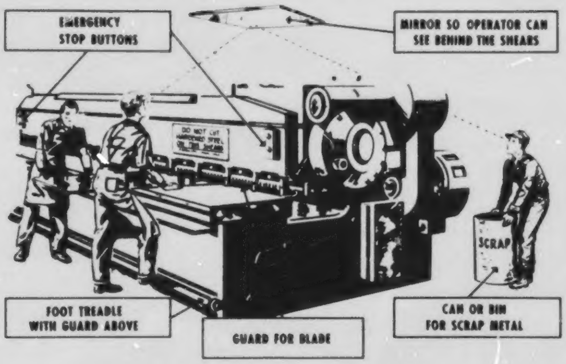
ANSI B11.4-1973 gives the American National Standard Safety Requirements for the Construction, Care and Use of Shears.

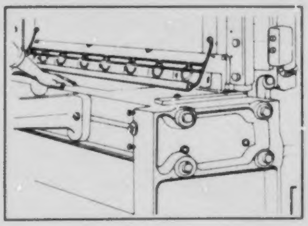
Mechanical and Operational Hazards and Controls

Power Transmission

Power shears may be driven by individual motors or from a lineshaft, comprised of belts and pulleys. All belts, pulleys, gears and motor couplings should be enclosed in standard guards of angle iron with a filler of wire mesh, or expanded, perforated sheet metal. Belt-driven shears should be equipped with positive acting and locking belt shifters.

POWER SHEARS


EMERGENCY STOP BUTTONS
MIRROR SO OPERATOR CAN SEE BEHIND THE SHEARS
DO NOT CUT HARDENED STEEL ON THE SHEARS
SCRAP
FOOT TREADLE WITH GUARD ABOVE
GUARD FOR BLADE
CAN OR BIN FOR SCRAP METAL



POWER SHEARS

Roller guard rests on sheet stock as it is fed into the shear. Descending ram will force roller out, and roller pushes operator's hands away from knife. When ram ascends, roller will rest in vertical position.

Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 48.

Figure 57

Start and stop buttons on motor-driven shears should be located within easy reach of the operator, preferably where they cannot be accidentally struck. An emergency stop button and a main power disconnect are required.

Point of Operation

Hazards at the point of operation include contact with the blade or knife on the feed side and at the rear of the machine and accidental tripping of the power shear.

The shear may be guarded with a fixed barrier guard which extends the length of the table and conforms to the maximum safe openings listed in Table 22 earlier in this unit. The fixed barrier, which admits the thickness of the metal but not the operator's fingers, is especially appropriate if the operator is working with stock of no more than 3/8 gauge.

Any slots, perforations or other openings in the guard should not exceed 1/4 inch between the knife or blade and the guard at all points. On foot and power operated shears, this guard should be located in front of the hold-down, which can be guarded separately, or as part of the knife guard.

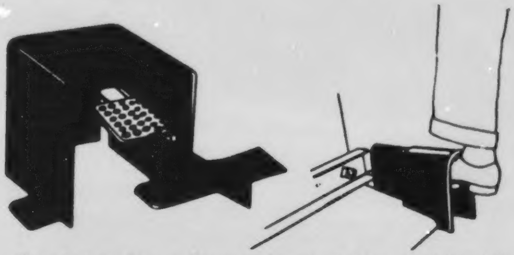
The back of the knife should be so guarded that a person cannot get his fingers under the knife. Before putting the shears in operation, the operator should always be sure that everyone is in the clear.

Gauges larger than 3/8 should utilize semi-adjustable "awareness barriers," which admit heavier stock but curtain the areas to each side of the stock being sheared. The operator is thus warned against further movement into the danger zone.

A hold-down device at the infeed side should be provided. It should be capable of restraining the material from being forced upward during the shearing stroke.

Foot Treadle Guard

The foot treadle should be equipped with a guard, running the full length of the treadle, so arranged that the treadle cannot be accidentally tripped.



Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 134.

Boxes, bins or other containers should be provided and used to keep scrap off the floor.

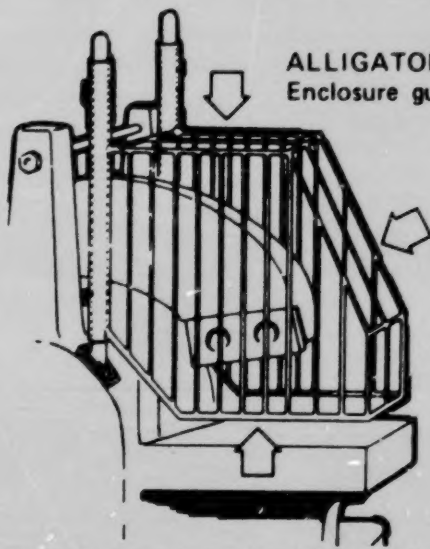
Because cutting hardened steel probably would damage the machine and injure the operator, a warning sign reading "Do not cut hardened steel" should be placed on every shear. A plate showing the cutting capacity also should be displayed.

Only experienced operators should be allowed to operate shears. Operators should wear snugly fitted clothes and safety shoes.

Alligator Shears

While not power shears in the truest sense, alligator shears deserve mention because they cause far more injuries than their inherent hazards and frequency of use warrant. Alligator shears chop rather than cut. They are used for cutting heavy bar or rod stock to more convenient length.

Because the alligator shear operates continuously, the operator must time his movements to coincide with the opening and closing of the cutter. An adjustable guard placed at the point of operation can prevent most finger and hand injuries.



ALLIGATOR SHEARS
Enclosure guard.

Reprinted from *Occupational Safety and Health in Vocational Education* (Cincinnati: NIOSH, 1979), p. 134.

If possible, a long bench should be built to the right or left of the shear and the material slid along and through the cutter.

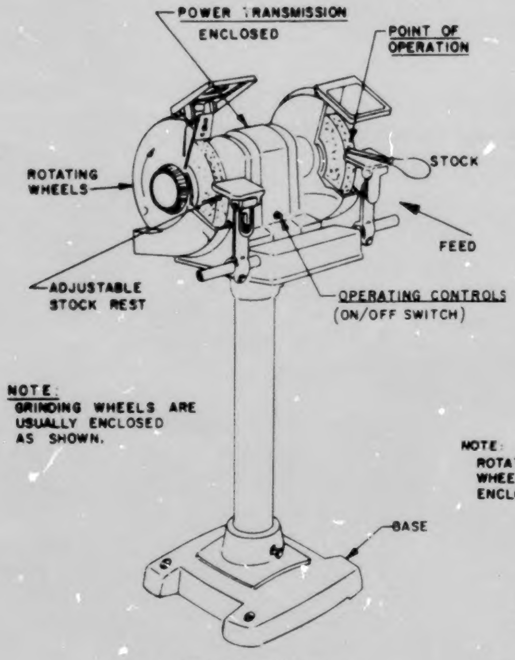
GRINDING MACHINES

Grinding machines shape material by bringing it into contact with a rotating abrasive wheel or disk. Polishing, buffing, honing and wire brushing are also classed as grinding operations. The most common grinding machines are:

1. stand and bench grinders (see Figure 58)
2. surface grinders (see Figure 59)
3. cylindrical grinders (see Figure 60).

Applicable Standards

The major hazards with all grinding machines are related to the rotating abrasive wheel. ANSI B7.1-1970 forms the American National Standard Safety Code for the Use, Care and Protection of


POWER TRANSMISSION ENCLOSED
POINT OF OPERATION
ROTATING WHEELS
STOCK
FEED
ADJUSTABLE STOCK REST
OPERATING CONTROLS (ON/OFF SWITCH)
NOTE: GRINDING WHEELS ARE USUALLY ENCLOSED AS SHOWN.
BASE

STAND GRINDER

Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 46.

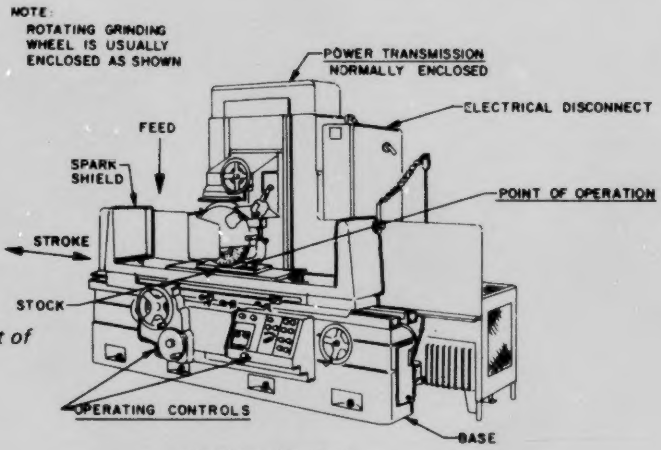
Figure 58

←

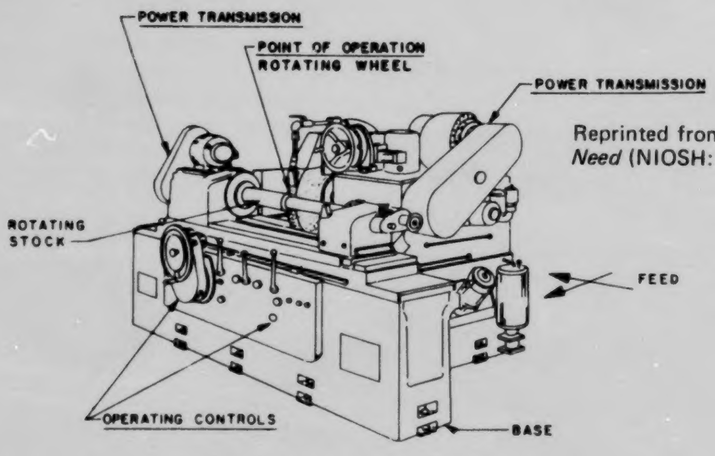
Reprinted from *Machine Guarding—Assessment of Need* (Cincinnati: NIOSH, 1975), p. 47.

Figure 59

→


NOTE: ROTATING GRINDING WHEEL IS USUALLY ENCLOSED AS SHOWN
POWER TRANSMISSION NORMALLY ENCLOSED
ELECTRICAL DISCONNECT
FEED
SPARK SHIELD
POINT OF OPERATION
STROKE
STOCK
OPERATING CONTROLS
BASE

SURFACE GRINDER


POWER TRANSMISSION
POINT OF OPERATION ROTATING WHEEL
POWER TRANSMISSION
ROTATING STOCK
FEED
OPERATING CONTROLS
BASE

CYLINDRICAL GRINDER

Reprinted from *Machine Guarding—Assessment of Need* (NIOSH: Cincinnati, 1975), p. 48.

Figure 60

←

Abrasive Wheels. Parts of this standard have been adopted in the General Industry OSHA Safety and Health Standards (29 CFR 1910.215, Abrasive Wheel Machinery).

Point of Operation Hazards

Hazards at the point of operation include:

1. work getting caught between tool rest (or guard) and wheel
2. hands coming into contact with the wheel
3. clothing getting caught by wheel or spindle ends.

Abrasive Wheel Hazards

Injuries involving the abrasive wheel and disks arise from:

1. failure to use eye protection in addition to the eye shield mounted on the grinder
2. holding the work incorrectly
3. incorrectly adjusting the work rest or using the machine without a work rest
4. grinding on the side of the wheel
5. taking too heavy a cut
6. applying work too quickly to a cold wheel or disk
7. grinding too high above the center of a wheel
8. failing to use wheel washers (blotters)
9. using bearing boxes with insufficient bearing surface
10. using a spindle with incorrect diameter
11. using a spindle with the threads cut so that the nut loosens as the spindle revolves
12. dressing the wheel incorrectly
13. using an abrasive saw blade instead of a grinder disk.[7]

Wheel Explosion

The hazard of flying fragments because of the disintegration or "explosion"of the abrasive wheel results from:

1. improper mounting of the wheel
2. cracks or flaws in the wheel
3. incorrect wheel for the work
4. wheel being run too fast
5. flanges (lack of flanges, unequal size, etc.)
6. vibration caused by the wheel's being out of balance, worn bearings, etc.
7. side pressure on wheels not designed for that work
8. work being caught between tool rest or guard and the wheel
9. particles from the material being ground as well as wheel particles.

If the wheel starts vibrating or chattering, it must be stopped. Usually such vibration means that the wheel is not securely attached or is out of balance.

Power Transmission

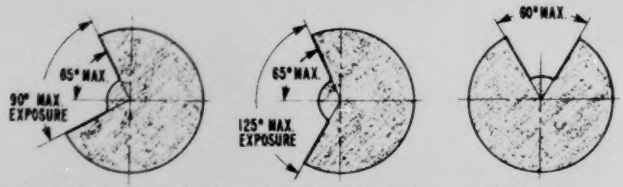
Power transmission (shafting, belts, pulleys, etc.) must be guarded in accordance with ANSI standards.

Guarding Abrasive Wheels

Abrasive wheels must be guarded in accordance with ANSI standards which have been adopted by OSHA. The guard should enclose the wheel as completely as the nature of the work permits. It should be adjustable so that, as the diameter of the wheel constantly decreases, the protection will not be lessened. The maximum angular exposure varies with the type of grinder (see Figure 61).

OSHA regulations state:

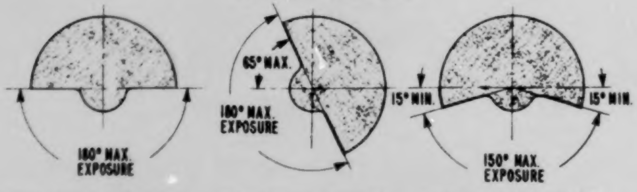
> *Bench and floor stands.* The angular exposure of the grinding wheel periphery and sides for safety guards used on machines known as bench and floor stands should not exceed 90 degrees or one-fourth of the periphery. . . .



BENCH AND FLOOR STAND GRINDERS

BENCH AND FLOOR STAND GRINDERS (WHEEL CONTACT) BELOW ℄ OF SPINDLE

TOP GRINDER



SWING-FRAME GRINDER

CYLINDRICAL GRINDER

SURFACE GRINDERS AND CUTTING-OFF MACHINES

Reprinted from *Accident Prevention Manual for Industrial Operations,* 7th ed. (Chicago: National Safety Council, 1974), p. 849.

Figure 61

Wherever the nature of the work requires contact with the wheel below the horizontal plane of the spindle, the exposure shall not exceed 125 degrees.

Cylindrical grinders. The maximum angular exposure of the grinding wheel periphery and sides for safety guards used on cylindrical grinding machines shall not exceed 180 degrees. This exposure shall begin at a point not more than 65 degrees above the horizontal plane of the wheel spindle.

Surface grinders and cutting-off machines. The maximum angular exposure for safety guards used on cutting-off machines and on surface grinding machines which employ the wheel periphery shall not exceed 150 degrees. This exposure shall begin at a point not less than 15 degrees below the horizontal plane of the wheel spindle.

Swing frame grinders. The maximum angular exposure of the grinding wheel periphery and sides for safety guards used on machines known as swing frame grinding machines shall not exceed 180 degrees, and the top half of the wheel shall be enclosed at all times.

There are cases of grinding where only the top of the wheel is used. OSHA regulations state:

> Where the work is applied to the wheel above the horizontal centerline, the exposure of the grinding wheel periphery shall be as small as possible and shall not exceed 60 degrees.

Storage

Suitable racks, bins or drawers should be provided to store the various types of wheels used. Stored wheels should not be subject to extremes of temperature and humidity. Wheels can be damaged by high humidity and/or freezing temperatures.

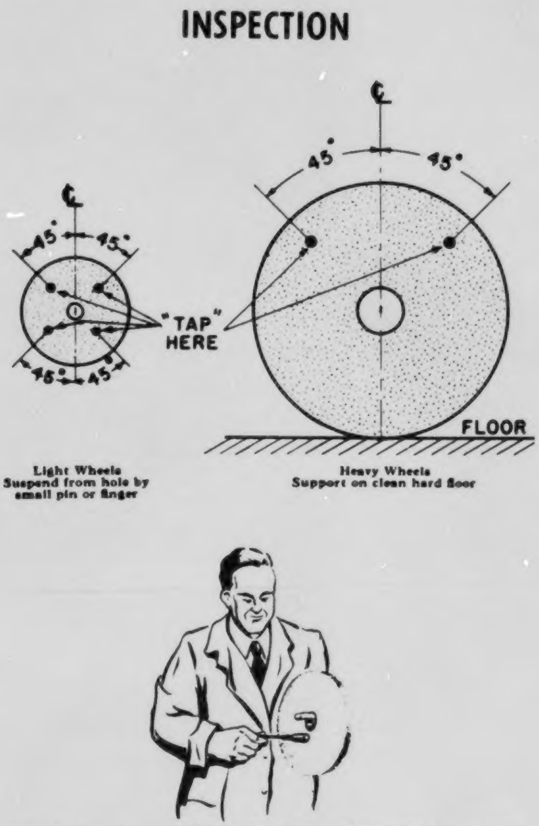
Inspection

A method of inspecting abrasive wheels has been mandated by OSHA. The requirements describe in some detail the ring test to be used:

> Immediately before mounting, all wheels shall be carefully inspected and sounded by the user (ring test) to make sure they have not been damaged in transit, storage or otherwise. The spindle speed of the machine shall be checked before mounting of the wheel to be certain that it does not exceed the maximum operating speed marked on the wheel. Wheels should be tapped gently with a light nonmetallic implement, such as the handle of a screwdriver for light wheels, or a wooden mallet for heavier wheels. If they sound cracked (dead), they shall not be used.
>
> Wheels must be dry and free from sawdust when applying the ring test; otherwise the sound will be deadened. It should also be noted that organic bonded wheels do not emit the same clear metallic ring as do vitrified and silicate wheels.
>
> Tap wheels about 45 degrees each side of the vertical centerline and about 1 or 2 inches from the periphery (see Figure 62). Then rotate the wheels 45 degrees and repeat the test. A sound and undamaged wheel will give a clear metallic tone. If cracked, there will be a dead sound and not a clear ring. This is known as the "ring" test.

Testing New Wheels

Because most defective wheels break when first started, new wheels should be run at full operating speed for at least one


INSPECTION
℄
45°
45°
"TAP" HERE
FLOOR
Light Wheels Suspend from hole by small pin or finger
Heavy Wheels Support on clean hard floor

Reprinted from *Basic Principles of Machinery Safeguarding,* U.S. Department of Labor, Bulletin 276 (1965), p. 54.

Figure 62

minute before work is applied. During this test period, the operator should stand well away from the machine.

Adjusting Spindle Speed

As the wheel wears down, the spindle speed is sometimes increased to maintain the surface speed. Therefore, when the worn wheel is replaced, the spindle speed must be adjusted. Otherwise the new wheel may break because it is operating at a surface speed that exceeds the manufacturer's recommendations.

Limiting Wheel Diameter

Grinding machines should be provided with a means of limiting the diameter of the wheel which can be mounted. The safety guard is generally satisfactory for this purpose on single speed machines.

On variable speed machines, the speed shifting device should be connected with an adjustable guard or another diameter limiting device to prevent the mounting of a wheel which might run at higher than the recommended surface speed.

Maintaining Grinding Equipment

When operating grinding wheels on equipment especially designed for high speed, it should be the responsibility of the user to maintain this equipment in safe operating condition at all times. Rules for the safe operation of this equipment submitted by the builder should be observed.

Altered Machinery

If an existing machine is altered by the user to operate at special speeds, the user must assume all of the responsibility of the machine builder.

Inform All Operating Personnel

The user should fully inform all operating personnel that only wheels identified for operation at special speed should be used and that at no time should the maximum speed marked on the wheel be exceeded. Protection to operating personnel, as well as adjacent areas, should be maintained at all times.

Power

Grinding machines should be supplied with sufficient power to maintain the rated spindle speed under all conditions of normal operation.

Exhaust Provisions

Stationary machines used for dry grinding should have provision made for connection to an exhaust system.

Flanges

Flanges are collars, disks or plates between which wheels are mounted. Grinding machines must be equipped with flanges in accordance with OSHA requirements:

> All abrasive wheels shall be mounted between flanges which shall not be less than 1/3 the diameter of the wheel. Exceptions:
>
> 1. mounted wheels
> 2. portable wheels with threaded inserts or projecting studs
> 3. abrasive disks (inserted nut, inserted washer and stud type)
> 4. plate mounted wheels

5. cylinders, cup or segmental wheels that are mounted in chucks
6. types 27 and 28 wheels
7. certain internal wheels
8. modified types 6 and 11 wheels (terrazzo).

Because the major stresses produced in an operating grinding wheel tend to combine and become greatest at the hole, stresses due to mounting and driving should act as far from the hole as practicable. This is best accomplished by using flanges at least as large as one-third the diameter of the wheel.

OSHA recognizes three types of flanges: straight relieved flanges, straight unrelieved flanges and adaptor flanges.

1/16" = 1.6 mm.

Straight relieved flanges "shall be recessed at least 1/16 inch on the side next to the wheel" at a distance which is specified in the dimensions for these flanges. Straight flanges of the adaptor or sleeve type "shall be undercut so that there will be no bearing on the sides of the wheel within 1/8 inch of the arbor hole."

1/8" = 3.2 mm.

OSHA further requires that flanges "be dimensionally accurate and in good balance. There shall be no rough surfaces or sharp edges." Although exceptions are made for Type 27 and 28 wheels and modified Types 6 and 11 wheels, OSHA requires that both flanges between which a wheel is mounted "shall be of the same diameter and have equal bearing surface."

All flanges must be maintained in good condition. "When the bearing surfaces become worn, warped, sprung or damaged, they should be trued or refaced."

Blotters

Blotters are used for several reasons. They tend to cushion the pressure of the flanges against high points or uneven surfaces and distribute the pressure evenly. They prevent damage to the surfaces of the flanges from the abrasive surface of the wheel. They provide better transmission of the driving power to the wheel.

OSHA requires that "blotters (compressible washers) shall always be used between flanges and abrasive wheel surfaces to insure uniform distribution of flange pressure." Exceptions are made for those kinds of wheels which do not require flanges.

Work Rests

OSHA requires:

> On offhand grinding machines, work rests shall be used to support the work. They shall be of rigid construction and designed to be adjustable to compensate for wheel wear.

The rest never should be adjusted while the wheel is in motion. The rest may slip, strike the wheel and break it; or the operator may catch his finger between the wheel and the rest.

Safe Operation

The industrial/vocational education teacher or supervisor who wants to promote shop safety will take some additional steps when grinding machines are used.

Proper Training

He will make sure that the students are trained in the hazards presented by grinding machines.

Replacing Safety Guard

He will be certain that, when a wheel has been mounted, the safety guard is properly positioned before the wheel is started.

Starting the Wheel

He will be certain that the grinding machine is run at operating speed with the safety guard in place for at least one minute before any work is applied. During this test period he will make sure that no one stands near the machine.

Investigation After Breakage

When a grinding wheel is broken in service, the instructor must initiate an investigation immediately to find out why the wheel broke. In this way, not only will he be certain that the shop is in compliance with all state and federal regulations but also he will take steps to prevent breakage in the future.

SUMMARY

We have examined in this unit the fundamental issues involved in machine guarding. The hazardous mechanisms which need to be safeguarded have been described. OSHA requirements for guarding at the point of operation and at the power source have been detailed along with suggestions for safe operation of machines commonly found in the industrial/vocational education shop. The basic types of guards have been described, and the characteristics of good guards have been discussed.

As part of the safety and health program in the school shop, machine guarding is not optional but mandatory. With the information derived from this unit, the industrial/vocational education instructor and supervisor can evaluate whether the machines in their shops are guarded adequately and can take the necessary steps to comply with regulations devised for their well-being and the welfare of the students who work in their shops.

NOTES

1. *Accident Prevention Manual for Industrial Operations*, 7th ed. (Chicago: National Safety Council, 1974), p. 795.

2. *Guards Illustrated*, 3rd ed. (Chicago: National Safety Council, 1973), p. xiii.

3. Adapted from *Supervisors Safety Manual*, 5th ed. (Chicago: National Safety Council, 1978), p. 297.

4. Adapted from ANSI 0.1.1, American National Standard, Safety Requirement for Woodworking Machinery, 1971, p. 22.

5. American National Standard Safety Requirements for Woodworking Machinery, pp. 18–19.

6. American National Standard Safety Requirements for Woodworking Machinery, p. 19.

7. Adapted from *Accident Prevention Manual*, pp. 841–842.

QUESTIONS AND ANSWERS

1. What is guarding?

Guarding is a means of effectively preventing workers from coming into contact with those moving parts of machinery or equipment which could cause physical harm.

2. Name three sources of injury that guarding can protect against.

Any three from among the following:

a. direct contact with the moving parts of a machine

b. contact with work in progress

c. mechanical failure

d. electrical failure

e. human failure (error).

3. What are three of the five hazardous mechanisms which need to be safeguarded?

Any three from among the following:

a. rotating mechanisms

b. cutting and shearing mechanisms

c. inrunning nip points

d. screw or worm mechanisms

e. forming or bending mechanisms.

4. What hazard is presented by an inrunning nip point?

A nip point draws in objects, including parts of the body, and crushes, mangles or flattens them.

5. What are the two points at which guarding is required?

a. point of operation

b. power transmission

6. What is a point of operation?

The point of operation is the area on a machine where the work is actually performed upon the material.

7. Name the four basic types of guards and indicate which is the preferred type.

a. fixed enclosure

b. interlocking

c. automatic

d. remote control, placement, feeding and ejecting

The fixed enclosure guard is the preferred type.

8. In this unit we have outlined ten requirements for an acceptable guard. Name six.

Any six from among the following:

a. It should protect the operator.

b. It should protect others nearby.

c. It should be a permanent part of the machine.

d. It should be convenient.

e. It should prevent access to the danger zone.

f. It should allow access for servicing.

g. It should be durable.

h. It should be easy to repair.

i. It should not create an accident hazard in itself.

j. It should conform to appropriate standards.

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UNIT 16

SAFETY AND HEALTH CONSIDERATIONS IN WELDING AND CUTTING OPERATIONS

METHODS Lecture and Demonstration **LENGTH: 60 Minutes**

PURPOSE To teach the participant to recognize and control safety and health hazards in welding and cutting operations.

OBJECTIVES To inform the participant of the:

1. Safe handling and storage of compressed gas cylinders
2. Safe use of welding equipment components
3. Steps in setting up the apparatus, lighting the torch and shutting down the apparatus
4. Hazards presented by arc welding
5. Locations where welding and cutting are prohibited
6. Specific responsibilities of instructors and/or supervisors in creating a safe working environment.

SPECIAL TERMS

1. Valve Protection Cap
2. Creeping
3. Reverse-Flow Check Valve
4. Backfire
5. Flashback

INSTRUCTOR MATERIALS

Lesson Plan
35 mm Slides, Projector and Screen
Chalk Board/Chalk

TRAINEE MATERIALS Participant Outlines and Supplementary Materials

UNIT 16

SAFETY AND HEALTH CONSIDERATIONS IN WELDING AND CUTTING OPERATIONS

INTRODUCTION

In our discussion of health hazards in Unit 13, the dangers of some common processes and operations in the industrial/vocational education shop were listed. For welding and cutting, the hazards arise from toxic gases and fumes, radiation, electrical circuits and flammable and combustible materials. This unit will describe safe operating procedures in welding and cutting, procedures which remove or at least minimize hazards while improving the quality of the work done. We first will examine gas welding and oxygen cutting and then proceed to arc welding. Finally we will see in what locations welding and cutting are prohibited and what are the specific responsibilities of the industrial/vocational education instructor and supervisor.

DEFINITIONS

Gas Welding

A gas-welding process unites metals by heating them with the flame from the combustion of a fuel gas or gases. Sometimes the process includes the use of pressure and a filler metal.

Oxygen Cutting

An oxygen-cutting process severs or removes metal by the chemical reaction of the metal with oxygen at an elevated temperature maintained with heat from the combustion of fuel gases.[1]

WELDING AND CUTTING GASES

Oxygen

The presence of oxygen is required to support any burning process. Oxygen must be combined with a "fuel" gas to produce the desired operating flame. Oxygen itself is not flammable or explosive; however, the presence of pure oxygen drastically increases the speed and force with which burning takes place. Its presence can turn a small spark into a roaring flame. Combustible materials burn much more rapidly in oxygen than in air. Oxygen also forms explosive mixtures in certain proportions with acetylene and other combustible gases.

Oxygen Cylinders

Oxygen is ordinarily supplied in standard drawn steel cylinders. The 244-cubic foot cylinder is the most commonly used, but smaller and larger sizes are available. Full oxygen cylinders are pressurized from 2000 to 2600 pounds per square inch. Oxygen cylinder contents can be determined by reading the cylinder pressure gauge on the regulator when in use. Half the full cylinder pressure rating indicates that half the volume (cubic feet) of oxygen remains. The maximum charging pressure is always stamped on the cylinder.

Labeling Oxygen Cylinders

Oxygen always must be labeled with its proper name "oxygen." It must never be labeled "air." Serious injury easily may result if oxygen is used as a substitute for compressed air. Oxygen should never be used in pneumatic tools, in oil preheating burners, to start internal combustion engines, to blow out pipe lines, to dust clothing or work, to create pressure or for ventilation.

Keeping Oxygen Away from Grease and Oil

In cylinders of oxygen, there is as much as 2600 psig pressure. When the pressure is released from the cylinder through the regulator, the speed at which the oxygen travels exceeds the speed of sound, and heat and friction are generated. Oil and grease become highly explosive in the presence of oxygen under pressure. Every gauge made to be used with oxygen has this information printed on the side of it. OSHA requires (in 1910.252):

> Cylinders, cylinder valves, couplings, regulators, hose and apparatus shall be kept free from oily or greasy substances. Oxygen cylinders or apparatus shall not be handled with oily hands or gloves. A jet of oxygen must never be permitted to strike an oily surface or greasy clothes or to enter a fuel oil or other storage tank.

Acetylene

Acetylene is a combination of carbon and hydrogen (C_2H_2). It is produced when calcium carbide is submerged in water. The escaping gas from the acetylene generator is then trapped in a gas chamber to be compressed into cylinders or fed into piping systems.

6000°F = 3316°C

Acetylene burned with oxygen can produce a higher flame temperature (approximately 6000°F) than any other gas used commercially. It ignites readily and in certain proportions forms a flammable mixture with air or oxygen. Its range of flammable limits is from 2.5 to 81 percent acetylene in air, a range greater than that of other commonly used gases.

Acetylene is an unstable gas when compressed in its gaseous state above 15 psig. Under no condition, states OSHA, "shall acetylene be generated, piped or utilized at a pressure in excess of 15 psig."

This requirement does not apply to the storage of acetylene dissolved in a suitable solvent in cylinders approved by the U.S.

Department of Transportation. Unlike oxygen, acetylene, because of its unstable character, cannot be stored in a hollow cylinder under high pressure. Therefore, acetylene cylinders are filled with a porous material, creating in effect a solid as opposed to a hollow cylinder. The porous filling is then saturated with liquid acetone. When acetylene is pumped into the cylinder, it becomes dissolved in the liquid acetone throughout the porous filling and is held in a stable condition. Since acetylene is highly soluble in acetone at cylinder filling pressure, large quantities of acetylene can be stored in comparatively small cylinders at relatively low pressure.

Acetylene for welding and cutting is usually supplied in cylinders having a capacity up to about 300 cubic feet of dissolved acetylene under pressure of 250 psi at 70°F.

70°F = 21°C

Other Fuel Gases

Other fuel gases (e.g., propane, butane and their mixtures) are used with oxygen in torches, primarily for oxygen cutting. These are supplied in cylinders in liquid form, generally under various trade names.

HANDLING CYLINDERS

Applicable Standards

Serious accidents can result from the misuse and mishandling of compressed gas cylinders. ANSI Z49.1-1967, Safety in Welding and Cutting, establishes standards for the marking, handling and storage of cylinders. This standard forms the basis for OSHA 29 CFR 1910.252, the federal regulations applying to welding, cutting and brazing.

Marking Cylinders

OSHA states:

> Compressed gas cylinders shall be legibly marked, for the purpose of identifying the gas content, with either the chemical or the trade name of the gas. Such marking shall be by means of stenciling, stamping or labeling, and shall not be readily removable. Whenever practical, the marking shall be located on the shoulder of the cylinder.

It is illegal to tamper with the numbers and markings stamped into cylinders.

DOT Approval

Only cylinders which carry the approval of the U.S. Department of Transportation should be accepted. OSHA requires:

> All portable cylinders used for the storage and shipment of compressed gas shall be constructed and maintained in accordance with the regulations of the U.S. Department of Transportation.

Cylinders meeting these specifications are manufactured under close supervision, subjected to severe testing and provided with proper safety devices.

Moving Cylinders

Cylinders should be moved by tilting and rolling them on their bottom edges. Dragging and sliding cylinders across a surface should be avoided; such a practice exposes the cylinders to unnecessary wear. It is preferable to move cylinders in a suitable cradle or cart. When cylinders are transported by vehicle, they should be secured in position. According to OSHA, cylinders "shall not be dropped" or struck, nor should they be permitted to strike each other violently because "rough handling, knocks or falls are liable to damage the cylinder, valve or safety devices and cause leakage."

Valve Protection Caps

OSHA requirements state:

> All cylinders with a water weight capacity of over thirty pounds shall be equipped with means of connecting a valve protection cap or with a collar or recess to protect the valve.

Valve protection caps are designed to protect valves from damage. OSHA states that "valve protection caps shall not be used for lifting cylinders from one vertical position to another." Before raising oxygen cylinders from a horizontal to a vertical position, the cap should be properly in place and turned clockwise to be sure it is hand-tight.

Steadying Device

A suitable cylinder truck, chain or steadying device should be used to keep cylinders from being knocked over while in use.

Cylinder Truck

If a cylinder truck is used, care must be taken to ensure its safe condition. Worn or bent wheels should be replaced; support chains must be present and in good condition; and, if the truck is equipped with a braking device, such a device must be kept in working condition.

Used Only for Containing Gas

Cylinders must "never be used as rollers or supports, whether full or empty." Their only purpose is to contain gas.

Used in Rotation

Full cylinders of oxygen and fuel gas should be used in rotation as received from the supplier. Cylinders always should be considered full and handled as such unless otherwise marked. Accidents have occurred when containers under partial pressure were thought to be empty.

Empty Cylinders

Empty cylinders should be marked "empty" or "MT" and segregated from full cylinders to avoid confusion. They should be returned to the supplier as soon as possible. All valves must be closed, and valve protection caps must be in place.

Storing Valve End Up

According to OSHA, "acetylene cylinders shall be stored valve end up." If acetylene cylinders are stored in a horizontal position, the acetone in which the acetylene is dissolved has a tendency to settle out to the end of the cylinder. An explosion may occur when the cylinder is opened and the oxygen and acetone are ignited. Storing cylinders in an upright position also minimizes external corrosion of the cylinder walls.

OSHA further requires that "fuel gas cylinders shall be placed with valve end up whenever they are in use. Liquefied gases shall be stored and shipped with the valve end up."

Storing Inside Buildings

When cylinders are stored inside a building, the storage area must be well protected, well ventilated, dry and at least twenty feet away from highly combustible materials such as oil. Indoor storage of fuel gas is limited to a total of 2,000 cubic feet or 300 pounds of LP gas.

Kept Away from Hot Places

Cylinders must be kept away from stoves, radiators, furnaces or other hot places. They must not be placed where they might become part of an electric circuit.

Mixed Storage

20' = 6 m.   5' = 1.5 m.

Oxygen cylinders must be separated from fuel gas cylinders and combustible materials. OSHA requires "a minimum distance of twenty feet" or "a noncombustible barrier at least five feet high having a fire-resistance rating of at least one-half hour."

Assigned Storage Space

Storage areas must be located where cylinders will not be knocked over or damaged by passing or falling objects and where no one can tamper with them. Cylinders should be secured by such means as chains or partitions.

Outside Storage

Where cylinders are stored outside, they should be protected from accumulations of ice, snow and the direct rays of the sun in localities where extremely high temperatures prevail.

Prying Loose Cylinders

According to OSHA:

> Bars and similar devices shall not be used under valves or valve protection caps to pry cylinders loose when frozen to the ground or otherwise fixed; the use of warm (not boiling) water is recommended.

Use of T-Wrench

A special T-wrench or key for opening or closing the cylinder valve on fuel gas cylinders must always be in position for use, so that the gas can be turned off quickly in case of emergency.

Filling Cylinders

Filling cylinders is a delicate process requiring special equipment and training. Therefore, OSHA states that only the gas supplier is allowed to mix gases in a cylinder and that "no one, except the owner of a cylinder or person authorized by him, shall refill a cylinder."

PROTECTIVE EQUIPMENT, REGULATORS AND HOSES

Protective Equipment

Fuel gas piping must have approved protective equipment installed in it to prevent:

1. backflow of oxygen into the fuel gas supply system
2. passage of a flashback into the fuel gas supply system
3. excessive back pressure of oxygen in the system.

Back-pressure protection requires an approved pressure-relief device set at a pressure not greater than the pressure rating of the backflow and flashback protection devices.

Regulators

Regulators or reducing valves must be used on both oxygen and fuel gas cylinders to maintain a uniform gas supply to the torches at a correct pressure. Uncontrolled pressure is dangerous in itself. A properly adjusted regulator also acts as a safety device, tending to stop any flashback from entering the cylinder where it might cause serious damage.

Each regulator, whether oxygen or fuel gas, should be equipped with both a high pressure (contents) gauge and a low pressure (working) gauge. According to OSHA, "pressure-reducing regulators shall be used only for the gas and pressures for which they are intended."

Pressure gauges should be tested periodically for accuracy. If the gauges have been strained so that the hands do not register properly, the regulator must be replaced or repaired before it is used again.

Care of Regulators

When regulators are connected but not in use, the pressure-adjusting device should be released. Cylinder valves would never be opened until the regulator is drained of gas and the pressure-adjusting device fully released.

The regulator is a delicate piece of equipment and must be handled carefully at all times. Hammers or wrenches must not be used to open or close cylinder valves. According to OSHA, "the supplier shall be notified" if valves cannot be opened by hand.

If a regulator "creeps," the cylinder should be closed and the regulator removed for repairs. "Creeping" is indicated on the low pressure (delivery) gauge by a gradual increase in pressure after the torch valves are closed.

Reverse-Flow Check Valve

A reverse-flow check valve on the regulator and torch handle reduces the possibility of mixing gases in the hoses and regulators. Once the torch is lit, mixed gases will burn rapidly and can explode in the hoses, regulators or cylinders. Such an explosion can result in injury to the welder and serious damage to the equipment.

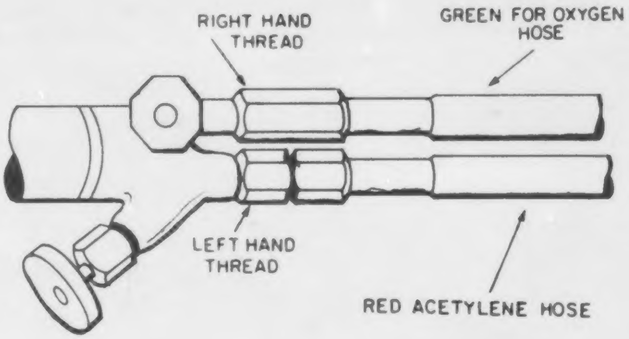
Reverse-flow check valves are screwed onto the regulator's outlet connection. They should be tightened securely with the proper wrench.

Hose and Hose Connections

Oxygen and acetylene hoses should be color coded to prevent confusion. According to ANSI, the generally recognized colors are:

- *red* for acetylene and other fuel gas hose
- *green* for oxygen hose
- *black* for inert gas and air hose.

Hose connections must be checked for proper threading. Standard hose connections are threaded right-hand for oxygen and left-hand for acetylene or other fuel gas. This helps prevent an accidental switch of oxygen and fuel gas hoses.



Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 11.

Single Hose Not to be Used

Oxygen and fuel gas hoses are not to be used interchangeably. A single hose having more than one gas passage should not be used.

Taping Hose

OSHA requirements state:

> When parallel sections of oxygen and fuel gas hose are taped together for convenience and to prevent tangling, not more than four inches out of twelve inches shall be covered by tape.

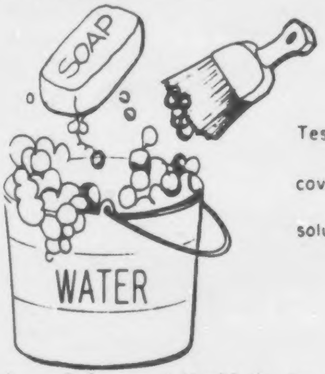
4" out of 12" = 10 cm. out of 30 cm.

Hose Couplings

Hose couplings must be of the type that cannot be unlocked or disconnected by means of a straight pull without rotary motion.

Testing for Leaks

The hose should be tested for leaks by immersing it, under normal working pressure, in water or by using soapy water (nonfat soap) or approved leaktest solution.



Test connections for leaks by covering with a leak-test solution of SOAPY WATER.

Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 12.

Leaks and worn places in the hose must be repaired at once by cutting the hose and remaking the joint with standard fittings. Leaks in the hose at the nipple connection should be repaired by cutting off the hose a few inches from the end and remaking the connection.

All leaks must be repaired at once. Escaping fuel gas may become ignited and start a serious fire. The OSHA standard requires, "Hose showing leaks, burns, worn places or other defects rendering it unfit for service shall be replaced or repaired." Splices are the only acceptable way of making repairs; taping is not satisfactory.

Testing Hose Connections

After repairing, hose connections should be tested. OSHA 1910.252 states:

> Hose connections shall be clamped or otherwise securely fastened in a manner that will withstand, without leakage, twice the pressure to which they are normally subjected in service, but in no case less than a pressure of 300 psi. Oil-free air or an oil-free inert gas shall be used for the test.

Caring for Hose

Hoses must be protected from flying sparks, hot slag or other hot objects and grease and oil. They should be stored in a cool place.

Unnecessarily long lengths of hose are to be avoided. They are hard to purge properly, and they tend to become kinked or tangled.

TORCHES

Torches are constructed of metal castings, forgings and tubing. Usually they are made of brass or bronze; stainless steel also may be used. Torches should be designed to withstand the rough handling they sometimes receive. Either they should be listed by Underwriters Laboratories, or they should be approved by an agency such as the Factory Mutual System.

Torches should not be used as hammers or to knock slag from work. Such misuse can deform the torch or tips. Slag hammers and wire brushes should be available.

Gases enter the torch by separate inlets. They go through the valves to the mixing chamber and then to the outlet orifice, which is located in the torch tip. Several interchangeable tips are provided with each torch. Their orifices are of various sizes to accommodate the work which needs to be done.

Unlike the welding torch, the cutting torch uses a separate jet of oxygen in addition to the jet(s) of mixed oxygen and fuel gas. The jets of mixed gases preheat the metal, and the jet of pure oxygen is used for cutting. The flow of oxygen to the cutting jet is controlled by a separate valve.

STEPS IN SETTING UP THE APPARATUS

Let us examine carefully each of the steps in setting up a gas welding and cutting operation. If the procedure outlined is followed, students in the industrial/vocational education shop can minimize the hazards to which they are exposed.

1. Inspect Valve Threads

First, inspect the cylinder valve threads. Remove dirt or dust with a clean cloth. If oil or grease is detected, do not use the cylinder.

2. Crack Cylinder Valve

Then "crack" each cylinder valve to dislodge any dirt, dust or rust that may be present. To "crack" the valve, momentarily open it slightly and then close it immediately. On a fuel gas cylinder, first make sure that no source of ignition is near. Otherwise the gas may ignite at the valve.

When "cracking" the valve, stand behind or to one side, not directly in front of the valve.

3. Inspect Regulators

Inspect the regulators. Remove dirt or dust with a clean cloth. If oil or grease is detected, the regulator must be cleaned by an authorized service representative. If threads are damaged, they must be repaired.

4. Attach Regulators to Valves

Connect the oxygen regulator to the oxygen cylinder valve. Tighten securely (clockwise) with a regulator wrench. Attach the fuel gas regulator to the fuel gas cylinder. Tighten it securely. Do not use a pipe wrench or pliers. Be sure that the connections between the regulators and the cylinder valves are gas-tight.

5. Release Tension on Adjusting Screws

Release tension on the pressure-adjusting screws on the regulator by turning them counterclockwise until they are loose. This step keeps the regulator and gauges from being damaged when the cylinder valve is opened.

6. Open Cylinder Valves

Being careful not to stand in front or in back of the regulator, open the cylinder valve slightly. Never open a cylinder valve suddenly; the rush of gas might strain the cylinder pressure gauge mechanism. Let the hand on the high pressure gauge move up *slowly* until maximum pressure is registered.

On an oxygen cylinder or any fuel gas cylinder other than acetylene, gradually open the valve to its full limit to completely seal the valve packing. On an acetylene cylinder, it is best to open the valve no more than 3/4 of a turn of the spindle; the valve must never be opened more than 1-1/2 turns.

7. Examine Hoses

Before attaching hoses to welding torch handle or regulator, examine them carefully. If cuts, burns, worn areas or damaged fittings are found, repair or replace the hose. If oil or grease is detected, do not use.

If the hose is new, blow it out with oxygen to remove preservative talc. For a fuel gas hose, cup one hose end against the outlet connection of the oxygen pressure-reducing regulator. Open the regulator to about five psi pressure to blow out the hose. Then blow through the hose from the mouth to purge it of concentrated oxygen.

8. Connect Oxygen Hose to Oxygen Regulator

Connect the oxygen hose to the outlet of the oxygen regulator. Adjust the oxygen regulator to allow three to five psig to escape through the hose. Allow oxygen to flow five to ten seconds to clear the hose of dust, dirt or preservative. Then shut off oxygen flow.

9. Connect Fuel Hose to Fuel Regulator

Attach and clear the fuel hose in the same manner.

10. Inspect Torch

Inspect torch handle head, valves and hose connections. Remove dirt or dust with clean cloth. Do not use the torch handle if oil or grease is detected or if parts are damaged.

11. Attach Hoses to Torch

Attach the oxygen welding hose to the oxygen inlet valve on the torch. Attach the fuel hose to the fuel inlet on the torch. Fuel reverse-flow check valves should be used on the torch handle. Tighten securely with a wrench.

12. Check for Leaks

Check for leaks with an approved leak-detector solution. Bubbles will appear if the connection is leaking. Test the following points for leakage: cylinder valve stem, regulator inlet connection at the cylinder valve, all hose connections and the torch valve.

If fuel gas leaks around the valve stem when the valve is opened, close the valve and tighten the gland nut. This compresses the packing around the spindle. If this does not stop the leak, close the valve and move the cylinder outdoors. Attach a tag to the cylinder stating that it should not be used. Notify the cylinder supplier immediately.

If fuel gas leaks from the cylinder valve and cannot be shut off with the valve stem or if rough handling should cause any of the fusible safety plugs to leak, the cylinder must be moved to an open place well away from any possible source of ignition and be plainly tagged as having an unserviceable valve or fusible plug. The cylinder should then have its valve opened slightly to let the acetylene escape slowly.

While the fuel gas is escaping from the cylinder, a sign must be placed close by to warn everyone against coming near the cylinder with a lighted cigarette or other source of ignition. To make sure that no fire occurs, a responsible person should stay in the area until the cylinder is depressured. The supplier should be notified promptly and his instructions followed as to the return of the cylinder.

Testing for hose leaks should be done in the manner described earlier in this unit.

13, Attach Proper Head, Tip or Nozzle to Torch

Always inspect cone end, coupling nut, welding tip and torch head before connecting. If damage, oil or grease is detected, do not use.

Connect the welding tip to the welding torch handle, and tighten the coupling nut. Some welding and cutting heads require only hand pressure when tightening; others require the use of a wrench. Follow the manufacturer's recommendation.

Always use the proper sized tip.

14. Adjust the Working Pressure and Purge Lines

With all torch valves closed, slowly open the oxygen cylinder valve. Open the torch oxygen valve. Turn in the pressure-adjusting screw on the oxygen regulator to the desired pressure. Close the torch oxygen valve.

Open the fuel gas cylinder valve (a maximum of 1-1/2 turns). With the torch fuel gas valve closed, turn in the pressure-adjusting screw to produce the desired pressure.

Purge each line separately. Open the oxygen torch valve and release oxygen to the atmosphere for a few seconds. Then close the valve. Do the same for the fuel gas, first making sure that there are no ignition sources nearby and that the area is well ventilated.

Use the proper gas pressures for the size of the head, tip or nozzle selected.

LIGHTING THE TORCH

In lighting the torch and adjusting the flame, always follow the manufacturer's directions for the particular model torch being used.

Precautions

The following precautions are necessary:

1. Always wear safety goggles when working with a lighted torch.
2. Never use matches for lighting torches. Hand burns may result from this practice. Use friction lighters, stationary pilot flames or a similar ignition source.
3. Never use acetylene at pressures above 15 psig. To do so is unsafe and violates OSHA standards, insurance regulations and, in many cases, municipal and/or state laws.
4. Always check the area to make certain that no ignition sources (flame, sparks, hot slag or metal, etc.) are present.
5. Never use equipment that has come in contact with oil or grease or that needs repairs.

Procedure

In general, four steps are followed in lighting the torch.

1. Open Torch Oxygen Valve

Open the torch oxygen valve to produce a small to moderate flow of gas (about 1/4 turn).

2. Open Torch Fuel Gas Valve

Open the torch fuel gas valve to produce a flow somewhat greater than the oxygen flow (about 1/2 turn).

3. Light Tip

Immediately light the mixture at the tip, using a friction lighter or stationary pilot flame. Point the flame away from persons and cylinders.

4. Adjust Flame

Adjust the flame by opening the torch oxygen valve until a bright neutral flame is reached.

BACKFIRES AND FLASHBACKS

A backfire is a loud popping or snapping noise associated with the momentary extinguishment of the flame at the torch tip. It may

Backfires

be caused by touching the tip against the work, by overheating the tip, by operating the tip at pressures other than those recommended, by a loose tip or head or by dirt on the seat. If the work is hot enough, the torch can be relighted at once.

If it cannot be relighted instantly, a torch lighter must be used. Before relighting the torch, the cause of the backfire should be determined.

Flashbacks

A flashback occurs when the flame burns back inside the torch or, if an explosive mixture is present in one of the lines, into hoses or regulators. Usually a flashback is accompanied by a shrill hissing or squealing. Sometimes there is a smoky or sharp pointed flame.

Causes of Flashbacks

A flashback indicates that something is very wrong, either with the torch itself or with the way it is being used. Flashbacks can be caused by failure to purge, improper pressures, distorted or loose tips or mixer seats, kinked hose, clogged tip or torch orifices or overheating the tip or torch.

Procedure

To stop the flashback at once, it is necessary to close the torch oxygen valve. Then the fuel gas valve should be closed and the torch allowed to cool off before relighting. Oxygen should be blown through the tip for a few seconds to clear out any soot which may have accumulated. In a cutting torch, oxygen should be blown through both the preheating and the cutting orifices. If a flashback burns the hose, the burned section must be discarded and any new hose purged before connecting it to the torch and regulator.

SHUTTING DOWN THE APPARATUS

When the welding operation is completed, certain steps must be taken to shut down the apparatus safely. This procedure prevents leaks which could cause a serious fire and reduces the likelihood of a regulator fire when the oxygen cylinder valve is opened again.

1. Shut Off Torch Valves

Shut off the fuel gas and oxygen valves in the order recommended by the torch manufacturer. If the oxygen valve is shut first, the fuel gas flame enlarges appreciably and the welder can be burned. Unburned fuel gas also escapes into the work area, sometimes in the form of carbon "feathers." However, if the fuel gas valve is shut first, a pop or band may occur. This noise can distract nearby workers, increasing the likelihood of accidents. It also throws carbon soot back into the torch, eventually partly clogging gas passages.

2. Close Cylinder Valves

Close both cylinder valves.

3. Open Torch Valves, Turn Out Pressure-Adjusting Screw and Close Torch Valves

Both the oxygen and fuel valves need to be drained in order to release all pressure from the hose and regulator. Pressures should not be relieved simultaneously.

Let the oxygen in the system drain out. Then close the oxygen valve. After the regulator gauge reading has reached zero, release the pressure-adjusting screw.

Follow the same procedure for the fuel valve. When releasing the fuel pressure, care must be taken that a fire hazard is not created by the release of fuel gas.

4. Uncouple Regulator

Uncouple the regulator. When regulators are to be out of service for several weeks or longer, it is good practice to turn in the pressure-adjusting screw just enough to move the regulator valve off its seat.

5. Remove Regulators Before Moving Cylinders

The regulators must be removed before moving the cylinders. Replace the cap over the cylinder valve when empty and mark the cylinder "MT."

Precautions

When shutting down the apparatus for a brief interval (less than an hour), close only the torch valves. Leave the hose and torch in an orderly fashion so that they will not be damaged.

Never hang a torch or hose on a regulator or cylinder valve unless the cylinder and torch valves are closed and the hose is drained of gas.

Never crimp hose to halt temporarily the flow of gases (for example, when changing a torch or tip).

When shutting down for an extended period, all apparatus should be disconnected and stored.

ARC WELDING AND CUTTING

Arc Welding

Arc welding is a process of joining metals by means of the heat created by an electric arc. The pieces to be welded are placed in position, and the intense heat of the electric arc applied to the joint melts the metal. Pressure may be applied, and filler metal may be used. When the joint cools, it becomes one solid piece.

Gas-Shielded Arc Welding

Shielded welding uses gas and flux to blanket the welding. It is used for joining metals which oxidize readily at high temperatures (e.g., copper, aluminum, stainless steel).

Arc Cutting

Arc cutting has been replaced for the most part with arc-oxygen cutting (especially useful for metals that do not oxidize readily), plasma arc cutting (for quality cuts), and carbon arc-air cutting (for smooth cuts).

Welding Leads

Arc welding and cutting require two welding leads, the electrode lead and the work lead, from the source of current. Usually one lead is connected to the electrode holder; the other cable, connected to the work, is the most satisfactory means of providing the grounding circuit to the welding machine.

Hazards

The principal hazards presented by arc welding are:

1. intense ultraviolet, visible and infrared radiation
2. production of ozone and nitrogen oxides
3. action of ultraviolet rays on chlorinated hydrocarbon vapors
4. production of toxic fumes from melting toxic metals or metal alloy
5. production of carbon monoxide
6. splatter of molten metal
7. handling high pressure gas in cylinders and manifolds
8. electrical shock.[2]

The first five hazards were discussed in Unit 13, Health Hazards (see especially Appendix B, Toxic and Corrosive Agents). In Unit 14, Personal Protective Equipment, the hazards presented by molten metal were examined. Earlier in this unit we outlined the requirements for handling compressed gas cylinders. The following discussion, while reviewing some of the other dangers, will emphasize the hazard of electrical shock.

RADIATION HAZARDS

Ultraviolet Radiation

Production of ultraviolet radiation is high in gas-shielded arc welding. For example, a shield of argon gas around the arc doubles the intensity of the ultraviolet radiation. With the greater current densities required (particularly with a consumable electrode), the intensity may be five to thirty times as great as with non-shielded welding.

Infrared Radiation

Infrared heats the tissue with which it comes in contact. Unless the heat causes an ordinary thermal burn, there is no harm.

Isolation of Welding Operations

Wherever possible, arc welding operations should be isolated so that other students will not be exposed to either direct or reflected rays. Walls, ceilings and other exposed inner surfaces should be painted with a finish of low reflectivity, such as zinc oxide and lampblack.

Arc welding stations for regular production work can be enclosed in booths if the size of the work permits. The inside of the booth should be painted with a finish of low reflectivity and provided with portable noncombustible or flameproof screens similarly painted or with curtains. Booths and screens should be designed to permit circulation of air at the floor level.

Welding should not be done near vapor-degreasing operations or spray booths. Such degreasing solvents as trichloroethylene can decompose under ultraviolet radiation and become dangerous.

Face and Eye Protection

OSHA requires (1910.252):

> Helmets or hand shields shall be used during all arc welding or arc cutting operations, excluding submerged arc welding. Goggles also should be worn to provide protection from injurious rays from adjacent work, and from flying objects. . . . Helpers or attendants shall be provided with proper eye protection.

"Goggles or other suitable eye protection" are also required during all gas welding or oxygen cutting operations.

OSHA requires that these helmets and hand shields "be made of a material which is an insulator for heat and electricity" and that they are not readily flammable.

Specifically, helmets and hand shields must be arranged "to protect the face, neck and ears from direct radiant energy from the arc."

If cracks occur in helmets or hand shields, they must be discarded immediately. The arc rays against which they no longer offer protection can cause serious burns.

2" = 5 cm.
4-1/8" = 10-1/2 cm.

Protective shields are provided with a glass window, the standard size being 2 inches by 4-1/8 inches. This glass protects the eyes from molten metal splatter. The glass must be composed so as to absorb the infrared rays, the ultraviolet rays and most visible rays emanating from the arc.

In selecting welding lenses and goggles, it is important to consider the manufacturer's reputation and his experience in the production of welding equipment, as well as the results of scientific tests of the lenses.

Unit 14 contains a discussion of eye and face protection. See especially Figure 37 (page 14-11), which illustrates various protectors and indicates which are recommended for specific operations, including welding. See also Table 18 (page 14-13), which gives the filter lens shade numbers to protect the eyes against particular welding operations.

In cases of irritation or flash burn, a physician should be consulted immediately.

Protective Clothing

Clothing must not only keep off the splatter and molten particles but also must obstruct the rays of the arc. An arc-burn on the skin resembles a sunburn except that it is usually more intense. Dark-colored shirts are preferred to light ones because arc rays readily penetrate light-colored fabrics.

Gloves should be worn at all times to protect the hands and wrists. When extensive welding operations are to be performed in the vertical and overhead positions, leather sleevelets, aprons and, in some cases, leggings should be employed to prevent severe burns from splatter and molten metal.

Handling Hot Metal

Students should be cautioned against picking up, either with bare or gloved hands, pieces of metal which have been welded or heated. The stub ends of discarded electrodes also can cause burns.

CONTAMINANTS

Another major hazard created by welding operations is the production of contaminants, either as byproducts or as the result of the operation itself. OSHA requires (1910.252):

> Local exhaust or general ventilating systems shall be

> provided and arranged to keep the amount of toxic fumes, gases or dusts below the maximum allowable concentrations . . .

Dilution Ventilation

For many welding and cutting operations, control by dilution ventilation is sufficient. That is, enough fresh air can be added to the contaminated air so that hazardous concentrations do not develop. However, the effectiveness of dilution ventilation depends on several factors:

- the size of the space in which welding or cutting is done, especially the height of the ceilings
- the total number of welders working within the space
- the hazardous chemical or physical agents produced by the welding or cutting.

OSHA requires mechanical ventilation when welding or cutting is done

- in a work space of less than 10,000 cubic feet per welder
- in a room less than sixteen feet high
- in confined spaces or where the welding space contains partitions, balconies or other structural barriers that obstruct cross ventilation.

16' = 5 m.

Otherwise, natural ventilation should be sufficient for most welding and cutting activities.

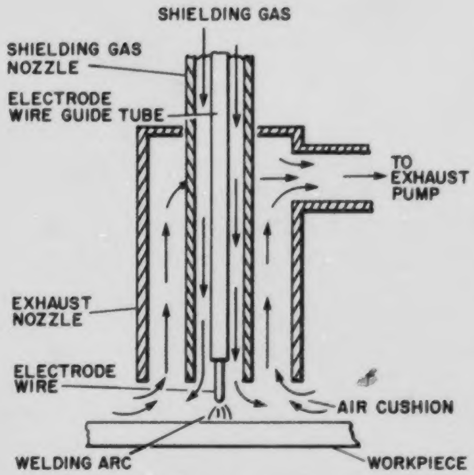
When dilution ventilation is used, it must move at least 2,000 cubic feet of air per minute per welder, unless local exhaust hoods and booths are used to control fumes where they are produced.

Local Exhaust Ventilation

In Unit 13 several methods of local exhaust ventilation were described: fixed enclosures, freely movable hoods and down-draft benches.

Extractor Nozzle

A new development in local exhaust ventilation is the extractor nozzle. In this system, a slotted exhaust chamber is installed as part of the welding equipment itself. The slotted exhaust chamber is positioned to allow the welder a clear view of the electrode. The contaminated air from the welding operation is drawn through the chamber to an exhaust system.


SHIELDING GAS
SHIELDING GAS NOZZLE
ELECTRODE WIRE GUIDE TUBE
TO EXHAUST PUMP
EXHAUST NOZZLE
ELECTRODE WIRE
AIR CUSHION
WELDING ARC
WORKPIECE

Design concept for welding gun.

Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 34.

Exhaust Gases

If gasoline-driven welding machines are operated indoors, exhaust gases must be piped outside in order to avoid carbon monoxide poisoning.

ELECTRICAL HAZARDS

Arc welding processes depend on the intense localized heat from applied electrical energy, not from a chemical reaction. Electrical hazards are many, but careful operation can prevent most accidents.

Open Circuits

The polarity switch changes the flow of electric current from one terminal to another; that is either from positive (reverse polarity) to negative (straight polarity) or the reverse. The range switch or tap switch helps the operator of a DC welding generator equipped with a system of tapping into the welding circuit to obtain the desired current setting. These switches should be operated only when the machine is idling and the welding circuit is open.

Open Circuits at High Current

Arcing is apt to occur if the circuit is open at high current, resulting in burns to

1. the person throwing the switch
2. the contact surfaces of the switch.

Grounding

Every power circuit should be grounded to prevent accidental shock. OSHA requires that the "grounding of the welding machine frame shall be checked. Special attention shall be given to safety ground connections of portable machines." Otherwise a stray current may give a severe shock if one hand is placed on the motor and the other on the switch box or other grounded equipment.

Conduits containing electrical conductors and pipelines must not be used to complete a work-lead circuit.

Electrodes and Electrode Holders

Arc welding is done with either a metallic or a carbon electrode. For gas-shielded metal arc welding, the electrode is a solid or flux-cored wire. For shielded metal arc welding, the electrode is a covered wire.

The electrode holder consists of a heat-resistant handle and a clamping device for holding the electrode. It is so designed that the electrode can be gripped firmly at any angle and held in that position. A fully insulated electrode holder reduces the likelihood of accidentally striking an arc.

Electrode holders will become hot during welding operations if holders designed for light work are used on heavy welding or if connections between the cable and the holder are loose.

The jaws of the electrode holder should be maintained tight and the gripping surfaces in good condition to provide close contact with the electrodes. Defective jaws will permit the electrode to wobble and render control of the welding operations difficult. The connection of the electrode lead to the holder should preferably be brazed. If the older type mechanical connection is used, it should be maintained tight at all times.

The voltage between the electrode holder and the ground, during the "off" arc period, is the open circuit voltage. Unless the welder uses the equipment provided for his protection, he can become exposed to this voltage while changing electrodes, setting up work or changing working position. This danger is particularly great during hot weather when he is perspiring.

The welder should keep his body insulated from both the work and the metal electrode and holder. He should never permit the bare metal part of an electrode, the electrode insulation or any metal part of the electrode holder to touch his skin or damp clothing. He never should change electrodes with wet gloves or bare hands or when standing on wet floors or grounded surfaces.

When welding is to be interrupted for more than an hour, OSHA requires that the machine be disconnected from the power source, that all electrodes be removed from the holders and that the holders be "carefully located so that accidental contact cannot occur."

OSHA regulations state:

> Electrode holders when not in use shall be so placed that they cannot make electrical contact with persons, conducting objects, fuel or compressed gas tanks.

When not in use, the electrode holder must never be left in contact with the table top or other metallic surface in direct contact with the welding ground. An insulated hook or holder should be provided for the electrode holder when not in use. The holder in contact with the ground circuit causes a dead short circuit on the welding generator. Should the machine be started up, this short circuit would cause an excessive load on the motor and could damage the insulation and fuses.

Great care must be taken to prevent accidental contact of the electrodes, electrode holders or other live parts with compressed gas cylinders. Very serious explosions or fire may occur from such contact.

Cables

Welding cables must not be subjected to currents in excess of their rating capacity. Otherwise overheating and rapid deterioration of the insulation would occur.

OSHA requirements state:

> Work and electrode lead cables should be frequently inspected for wear and damage. Cables with damaged insulation or exposed bare conductors shall be replaced. Joining lengths of work and electrode cables shall be done by the use of connecting means specifically intended for the purpose. The connecting means shall have insulation adequate for the service conditions.

If exposed sections of cable come in contact with metallic objects grounded in the welding circuit, an arc may result. If flammable material (e.g., oil or grease) happens to be in the vicinity, a fire may result.

All cable connections should be tight. OSHA requires that coiled welding cables "be spread out before use to avoid serious overheating and damage to insulation." OSHA also forbids the use of cables "with splices within ten feet" of the electrode holder.

10' = 3 m.

A welder should not coil or loop welding electrode cable around parts of his body.

OSHA regulations require that welding cable and other equipment be placed "clear of passageways, ladders and stairways."

Wiring

All wiring must be in compliance with the NFPA Code and local requirements.

Voltage

The voltage across the welding arc varies from fifteen to forty volts, depending on the type and size of electrode used. To strike the arc, the welding circuit must supply somewhat higher voltage. This is called the open circuit or "no load" voltage.

OSHA requires that open circuit voltages be as low as possible consistent with satisfactory welding or cutting. The following chart summarizes the OSHA regulations:

	Operation	
Type	Manual	Automatic (mechanized)
Alternating current	80 volts	100 volts
Direct current	100 volts	100 volts

Reprinted from *Safety and Health in Arc Welding and Gas Welding and Cutting* (Cincinnati: NIOSH, 1978), p. 9.

Switches

Proper switching equipment for shutting down the equipment must be provided.

PURCHASING, INSTALLING AND TRAINING

Equipment used for welding should be approved either by the National Electrical Manufacturing Association (NEMA) or by the Underwriters Laboratories.

The equipment must be installed by a qualified electrician, who is following the appropriate requirements of the National Electrical Code.

Students who are to do welding must be properly instructed in hazards of the operation and the safe practices which must be followed.

LOCATIONS WHERE WELDING AND CUTTING ARE PROHIBITED

Because of the hazards created by welding and cutting operations, great care must be taken in locating work sites where they do not create fire hazards or endanger students working nearby.

Because of the potential for fire and explosion, OSHA lists four locations where cutting or welding must not be permitted:

1. in the presence of explosive atmospheres (mixtures of flammable gases, vapors, liquids or dusts with air), or explosive atmospheres that may develop inside uncleaned or improperly prepared tanks or equipment which have previously contained such materials, or that may develop in areas with an accumulation of combustible dusts.

1. in areas near the storage of large quantities of exposed, readily ignitible materials.

3. in sprinklered buildings while such protection is is impaired.

4. in areas not authorized by management.

1. In the Presence of Combustible and Flammable Vapors, Liquids, Gases or Dusts

Welding and cutting operations should not be permitted in or near rooms containing flammable or combustible vapors, liquids, gases or dusts. They must also be prohibited on or inside tanks or other containers which previously held such materials unless these are first properly purged.

When fire and explosion hazards have been eliminated from areas formerly containing these flammable or combustible materials, thorough ventilation is necessary. Local exhaust equipment should be provided for removing the hazardous gases, vapors and fumes that ventilation fails to dispel.

OSHA requirements state:

> No welding, cutting or other hot work shall be performed on used drums, barrels, tanks or other containers until they have been cleaned so thoroughly as to make absolutely certain that there are no flammable materials present or any substances such as greases, tars, acids

or other materials which, when subjected to heat, might produce flammable or toxic vapors.

A cleansing agent should be used which is appropriate for the gas or liquid which was in the container. Then the container must be cleaned again, using either water or steam.

In cooperation with the American Welding Society, ANSI A6.0-1965 details Safe Practices for Welding and Cutting Containers That Have Held Combustibles.

2. Near Large Quantities of Exposed, Readily Ignitible Materials
35' = 11 m.

Welding and cutting operations should not take place near large quantities of exposed, readily ignitible materials. Such materials should be moved at least 35 feet away from the work site.

If neither the work nor the material can be moved, then combustibles must be protected with flameproof covers or sheet metal. According to OSHA, "edges of covers at the floor should be tight to prevent sparks from going under them."

Floors must be swept clean for a radius of 35 feet of such combustible materials as paper scraps, wood shavings and sawdust. It is best to cover floors with metal or other noncombustible material. Covering the floor with damp sand or wetting it down is a less desirable solution. The moisture increases the electrical shock hazard for arc welders and necessitates special protection.

OSHA requires:

> Where cutting or welding is done near walls, partitions, ceilings or roofs of combustible construction, fire-resistant shields or guards shall be provided to prevent ignition.

When welding is to be done on metal walls, partitions, ceilings or roofs, combustibles on the other side should be relocated. If combustibles cannot be relocated, OSHA requires that a "fire watch on the opposite side from the work" be provided.

Spark Guards

When it is not possible to move materials that will burn to a safe distance from the cutting or welding work, suitable protection must be used to keep back sparks. Areas should be inspected for floor openings or cracks through which sparks could fall or in which they could lodge. Guards must be large enough and tight enough so that they do not permit sparks to roll underneath or slide through openings. Curtains should be weighted down against the floor or ground so that sparks cannot possibly get underneath. Recommended weights are such objects as angle irons, pipes, bricks or sand. Only fire-resistant guards should be used for shielding sparks. Tarpaulins should not be used since they may catch fire.

Ducts and conveyor systems that might carry sparks to distant combustibles must be protected or shut down during welding or cutting. Because cutting produces more sparks and hot slag than does welding, safeguards against sparks are particularly important during cutting.

Fire Watchers

When welding or cutting is done near ignitible materials, a student should be assigned to see that sparks do not lodge in floor cracks.

OSHA regulations require fire watchers "whenever welding or cutting is performed in locations where other than a minor fire might develop" and in the following specific situations:

35' = 11 m.

1. where there is "appreciable combustible material" (either in materials or structural elements) closer than 35 feet to the welding or cutting operation
2. where "appreciable combustibles" are more than 35 feet away but are easily ignited by sparks
3. where wall or floor openings within a 35-foot radius expose combustible material in adjacent areas
4. where combustible materials "are adjacent to the opposite side of metal partitions, walls, ceilings or roofs and are likely to be ignited by conduction or radiation."

Fire watchers must have some specific training, according to OSHA:

> Fire watchers shall have fire extinguishing equipment readily available and be trained in its use. They shall be familiar with facilities for sounding an alarm in the event of a fire. They shall . . . try to extinguish (fires) only when obviously within the capacity of the equipment available, or otherwise sound the alarm. A fire watch shall be maintained for at least a half hour after completion of welding or cutting operations to detect and ex-

tinguish possible smoldering fires.

It is not realistic to expect the welder or cutter to be the fire watcher. His attention should be on his work, and his goggles will obscure his peripheral vision.

Fire Extinguishing Equipment

It is good practice to provide each welding booth with a Class B and C fire extinguisher of a dry chemical, multipurpose or carbon dioxide type. Pails of water and buckets of sand may be useful, particularly to catch the dripping slag from any cutting that is being done.

3. In Sprinklered Buildings While Protection is Impaired

If a sprinkler system needs to be shut down for a time, this should be done when no welding or cutting is in progress. OSHA prohibits cutting or welding "in sprinklered buildings while such protection is impaired."

4. In Areas Not Authorized by Management

According to OSHA standards, "cutting or welding shall be permitted only in areas that are or have been made fire safe." Such areas should be:

1. of noncombustible or fire-resistive construction
2. essentially free of combustible and flammable contents
3. suitably segregated from adjacent areas.

RESPONSIBILITIES OF INSTRUCTOR AND/OR SUPERVISOR

OSHA requirements assign specific responsibilities to supervisors, responsibilities equally applicable to instructors and supervisors in the industrial/vocational education shop. These include:

1. responsibility for "the safe handling of the cutting or welding equipment and the safe use of the cutting or welding process"
2. determining what combustibles and hazards are present in the work location
3. protecting combustibles from ignition by
    a. relocation of work
    b. relocation or shielding of combustibles
    c. careful scheduling of operations

4. giving the cutter or welder assurance that conditions are safe before work is begun
5. determining "that fire protection and extinguishing equipment are properly located"
6. seeing to it that fire watchers are on the site when conditions require their presence.

SUMMARY

The hazards presented by welding and cutting operations in the industrial/vocational education shop are considerable, but they can be controlled by allowing the operations only in fire safe locations, providing adequate ventilation, using the proper protective equipment and following the correct work procedure.

NOTES

1. Adapted from *Accident Prevention Manual for Industrial Operations*, 7th ed. (Chicago: National Safety Council, 1974), p. 948.
2. Adapted from *Gas-Shielded Arcs and Plasma-Jet Torches*, NSC Data Sheet 552 (Chicago: National Safety Council, 1965), p. 2.

QUESTIONS AND ANSWERS

1. **Why is it important to keep oil and grease from contact with oxygen under pressure?**

In the presence of oxygen under pressure, oil and grease become highly explosive.

2. **What provisions for hoses and hose connections prevent confusion of oxygen and fuel gas?**

The hoses are different colors: red for fuel gas and green for oxygen. Hose connections are threaded right-hand for oxygen and left-hand for fuel gas.

3. **To what degree should cylinder valves be opened?**

Oxygen valves should be opened gradually to their full limit; acetylene valves must never be opened more than 1-1/2 turns (3/4 of a turn is recommended).

4. **State four safety precautions to observe when lighting the torch.**

Any four from among the following:

a. Always wear safety goggles.

b. Never use matches for lighting the torch.

c. Never use acetylene at pressures above 15 psig.

d. Make sure that no ignition sources are present.

e. Never use equipment that has come in contact with oil or grease or that needs repairs.

5. What are the first steps to take to stop a flashback?

Close the torch oxygen and fuel gas valves.

6. In this unit we listed eight hazards presented by arc welding. Name four.

Any four from among the following:

a. radiation

b. production of ozone and nitrogen oxides

c. action of ultraviolet rays on chlorinated hydrocarbon vapors

d. production of toxic fumes from melting

e. production of carbon monoxide

f. splatter of molten metal

g. handling high pressure gases in cylinders or manifolds

h. electrical shock.

7. OSHA forbids cutting or welding in four locations. What are they?

a. in the presence of combustible and flammable vapors, liquids, gases or dusts

b. near large quantities of exposed, readily ignitible materials

c. in sprinklered buildings while such protection is impaired

d. in areas not authorized by management.

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UNIT 17

ELECTRICAL SAFETY

METHODS Lecture and Demonstration LENGTH: 60 Minutes

PURPOSE To provide a general understanding of electrical hazards in the industrial/vocational education shop and to show how they can be controlled.

OBJECTIVES To introduce the industrial/vocational education supervisor and instructor to:

1. The characteristics of electrical circuits
2. Factors affecting severity of electrical shock
3. Specific ways to protect the human body from becoming part of the conductive path
4. The requirements of the National Electrical Code which pertain to isolation, insulation, grounding and overcurrent protection

5. Ways to prevent damage to the electrical components of shop equipment.

SPECIAL TERMS

1. Current
2. Ampere
3. Voltage
4. Watt
5. Resistance
6. Ohm
7. Grounding
8. Dead-Front Construction
9. Pigtail Connector
10. Ground Fault
11. Reversed Polarity
12. Overcurrent Devices
13. Ground Fault Circuit Interrupter

INSTRUCTOR MATERIALS

Lesson Plan
35 mm Slides, Projector and Screen
Chalk Board/Chalk

TRAINEE MATERIALS Participant Outlines and Supplementary Materials

UNIT 17

ELECTRICAL SAFETY

INTRODUCTION

Most people have ambiguous feelings about electricity. On the one hand, they depend on it for everyday conveniences which they take for granted. On the other hand, they fear electricity. One reason is that electricity is the cause of many publicized deaths throughout the nation. Another reason is that people are unable to detect electrical signals through their senses until it is too late.

In industrial/vocational education shops the hazards associated with electricity (burns, shock, falls, electrocution, fire) are greatly increased by the numbers of power tools and equipment used by students involved in a variety of shop operations. When these students are unfamiliar with the safe practices necessary to ensure electrical safety, the dangers become even greater.

Why is an entire unit devoted to electrical safety? In the first place, as we saw in the unit on fire protection, almost one-fourth of industrial fires are caused by electrical malfunctions.

Secondly, in any given year over a thousand deaths result from direct contact with electrical current.[1] This figure does not include deaths in fires caused by electrical malfunctions, nor does it reflect injuries which are not fatal (e.g., burn injuries from electrical flashes).

Finally, electrical code violations are cited by OSHA five times more frequently than the next most common class of violations.[2] OSHA standards are those of the National Electrical Code, the universally accepted minimal requirements published mutually by the National Fire Protection Association and the American National Standards Institute. Since all electrical installations are supposed to comply with the requirements of the code, the number of violations is particularly noteworthy.

Purpose of Unit

The purpose of this unit is to enable instructors and supervisors to recognize and correct any electrical hazards existing in shop facilities. In this way fires can be prevented, electrical shock avoided and safe operations maintained.

DEFINITIONS

Before we examine electrical hazards further, it is important to define several key terms:

1. current, measured in amperes
2. voltage, measured in volts
3. power, measured in watts
4. resistance, measured in ohms.

Current

Current is the rate at which electricity flows through a circuit. It is measured in amperes. Because an ampere is a very large quantity in relation to its effect on the body, the milliampere (.001 amp) is used to measure electrical shock.

Alternating current (AC) is a current (measured in amperes) which alternates in frequencies measured in cycles per second (hertz, abbreviated Hz).

Voltage

Voltage is the pressure which causes electricity to flow through a circuit. Every electrical circuit requires an electrical path from one terminal of the power source to the load (the device that uses the power) and a return path from the load to the other terminal of the power source or to the ground. The voltage is the difference between the two power source terminals. The ground is literally the earth and is always at 0 voltage.

Voltage is equal to the product of current (amperage) and resistance (ohmage) and is measured in volts.

Power

Power is the amount of electricity that flows through the circuit. It is equal to the product of the voltage and the current (amperage) and is measured in watts.

Resistance

Resistance is anything that impedes or retards the flow of electricity. It is measured in ohms. Sometimes the term "resistance" is used to apply to direct current (DC), while the term "impedance" is applied to alternating current (AC).

FACTORS AFFECTING SEVERITY OF ELECTRICAL SHOCK

The severity of electrical shock is determined by the amount of current flow. The amount of current flow at which an individual

Current Flow

can still let go of an object held by the hand (before "freezing") varies from 10 to 16 milliamperes. Respiratory paralysis can occur with 30 milliamperes, and values greater than 75 milliamperes cause ventricular fibrillation, discoordinated heart action which usually results in death.[3]

Low Voltage vs. High Voltage

Sometimes a lower voltage is more dangerous than a higher one. Higher voltages cause such violent muscular contractions that the victim is thrown away from the circuit. Lower voltages may "freeze" the victim to the circuit. Since he is unable to let go, he is exposed to a longer current flow.

The mild shocks caused by even lower voltages can cause accidents. Because of muscular contractions, a person may lose his balance and fall.

What is frightening in these figures is the small quantity of electrical energy required to cause death. One researcher observes that the current drawn by a 7.5-watt, 120-volt lamp, passed from hand to hand or foot, is enough to cause fatal electrocution.[4] This amount of current is readily obtained on contact with low-voltage sources of the ordinary lighting or power circuit.

Resistance

Current flow depends on voltage and resistance. Resistance to current flow is mainly to be found in the skin surface. When the skin is moist, resistance decreases dramatically. Once skin resistance is overcome, current flows unimpeded through body tissues and blood. The chart below illustrates the findings of Charles F. Dalziel, who conducted pioneer studies in the field of electric shock.

HUMAN RESISTANCE TO ELECTRICAL CURRENT

Body Area	Resistance (ohms)
Dry skin	100,000 to 600,000
Wet skin	1,000
Internal body–hand to foot	400 to 600
Ear to ear	(about) 100

The protection offered by skin resistance decreases as voltage increases.

Variables

The severity of shock is determined by amperage, which depends on several variables:

- voltage, how much electricity is involved
- resistance, how many ohms impede the flow of voltage
- duration of current flow
- frequency of electrical waves (in an alternating current)
- part of the body exposed.

Static Electricity

Static electricity is stationary; it does not involve a current. The hazards of static electricity were discussed in Unit 12, Fire Protection.

ACCIDENT CIRCUIT

The Electrical Circuit

This unit is concerned with the hazards of electrical circuits. The term "circuit" suggests the continuous flow of electricity in the electrical system. The typical system consists of two conductors or wires which transmit the electrical energy. The electricity in one wire is under pressure and is trying to flow to the other wire. An electric current will flow through any conductive object which becomes connected between the two wires of the power system. The object of electrical safety is to prevent the human body from becoming part of the conductive path.

Neutral Conductor

In the conventional power system one of the conductors is physically connected to the earth. That portion of the power system is commonly referred to as the neutral conductor. Contact between the human body and the neutral side of the power system is usually established by touching or being connected to a grounded object. Students and school personnel easily can come in contact with the neutral side of the power system by touching such grounded objects as metal machinery, equipment or pipes. Grounded objects in direct contact with the human body provide an attraction or "drain" for stray currents from other pieces of equipment.

Hot Conductor

The hot side of the power system is the conductor which is not connected to the earth. In cases where the human body becomes part of the electrical circuit, the hot side is usually a piece of energized equipment or a wiring device. When an electrical current flows between the power circuit and any part of the equipment in contact with the body, then the human body which is in contact with some other grounded object becomes the path for the current. The body itself is grounded.

MEANS OF PROTECTION

What kinds of protection are possible to prevent current from flowing through the human body? Several types come to mind:

1. isolation
2. insulation
3. grounding
4. overcurrent protection.

Isolation

If the power system and the human body do not come in contact, there can be no accident circuit. Barriers and enclosures can prevent accidental contact with electrical equipment. Live parts should be enclosed whenever possible. Adequate machine guarding is an important part of an electrical safety program.

Insulation

Electrical equipment contains insulation between the power circuitry and other parts of the equipment. Currents cannot flow through the nonconductive materials used for insulation. If this insulating material deteriorates, very high and dangerous currents are released by the equipment. The breakdown in the insulation of cords and plugs is a frequent cause of electrical accidents. We will discuss electrical cords and fittings later in this unit.

Double insulated tools are accepted in the National Electrical Code as an alternative to grounding in certain areas. Such equipment has two complete and independent systems of insulation. Each system would have to break down in the same spot for shock danger to exist.

But there are limitations to double insulation.

1. Students may develop bad habits. For example, if students are being trained to look for the grounding pin on all attachment plugs, this "exception to the rule" will contradict rather than reinforce the practice which the instructor is advocating.

2. Few types of devices are available in double-insulated form.

3. Double insulation protects the user only from faults within the device itself. It does not protect the user from faulty cords or plugs.

Grounding

Equipment grounding directs possibly unsafe amounts of electricity to ground. Both equipment and electrical systems are grounded (see NEC 250-1).

Equipment grounding connects exposed noncurrent carrying metal parts of electrical equipment to ground. This grounding prevents a voltage above ground on these parts.

Electrical systems are grounded to limit excessive voltage from lightning, line surges or unintentional contact with higher voltage lines.

Both circuits and enclosures are grounded to cause overcurrent devices to operate in case of insulation failure or ground faults.

Overcurrent Devices

Overcurrent protection devices such as fuses and circuit breakers open the electrical circuit automatically in case of excessive current flow from ground, short circuit or overload.

We will now examine in more detail the subjects of the guarding of live parts, the use of flexible cords and plugs, grounding and overcurrent protection.

GUARDING OF LIVE PARTS

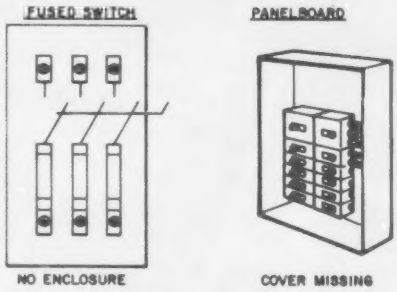
Description of Hazard

Parts connected to any conductor of electrical circuits should be considered "live." Current will flow over all possible paths between live parts or from a live part to ground.

This hazard can result from:

- insulation being damaged
- equipment being installed without enclosure
- enclosures or covers being removed.

There is always the danger of persons or objects coming into contact with live parts which are not completely enclosed. Persons becoming part of the path will be shocked. When metallic objects



Reprinted from "Electrical Hazards, OSHA and the National Electrical Code," Part IV, by William S. Watkins and Associates, Inc.

come into contact with live parts, the resulting short circuit can cause arcing (including blinding sparks) or molten metal splatter, either of which can in turn cause fires.

Applicable Standards

The Occupational Safety and Health Administration in its Safety and Health Standards (1910.309) specifies that the requirements in the National Electrical Code shall apply to the guarding of live parts. What are these requirements?

According to the NEC (110-17):

> Except as elsewhere required or permitted by this Code, live parts of electrical equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures, or any of the following means:
>
> 1. by location in a room, vault or similar enclosure that is accessible only to qualified persons
>
> 2. by suitable permanent, substantial partitions or screens so arranged that only qualified persons will have access to the space within reach of the live parts. Any openings in such partitions or screens shall be so sized and located that persons are not likely to come into accidental contact with the live parts or to bring conducting objects into contact with them
>
> 3. by location on a suitable balcony, gallery or platform so elevated and arranged as to exclude unqualified persons

8' = 2.4 m.

4. by elevation of 8 feet or more above the floor or other working surface.

In locations where electrical equipment would be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.

Entrances to rooms and other guarded locations containing exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter.

The intent of the code is to protect any person who is in the vicinity of electrical equipment from accidental contact. Provisions are made for arranging and locating equipment so that it is accessible only to qualified persons.

Prevention of Hazard

Several specific precautions can prevent contact with live parts and the resulting injuries:

1. Use covers, screens or partitions which require tools to remove them.
2. Make sure that, if covers are removed from such equipment as panels, motor covers or fuse boxes, they are replaced.
3. Provide guards or barriers if live parts cannot be enclosed completely.
4. Even when live parts are elevated the required eight feet, caution students about using in the vicinity objects such as long metal rods which can come into contact with these parts.
5. Instruct students who see exposed live parts to report the condition immediately so that it can be corrected. Unless it is simply a matter of closing a door, instruct students never to attempt to correct the condition themselves.
6. Close unused conduit openings in boxes so that pencils, metal chips and the like cannot enter.

8' = 2.4 m.

Working Clearances

Until now we have been concerned about preventing accidental contact with live parts. But the NEC has requirements to protect the person, presumably a trained electrician, who is qualified to work on the equipment. The NEC (110-16) requires: "Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment."

Briefly summarized, the code requires:

- a work space at least thirty inches wide in front of the electrical equipment
- adequate illumination
- sufficient access area to the working space
- minimum headroom of 6-1/4 feet.

30" = 76 cm.

6-1/4" = 1.9 m.

The code forbids storage of materials in the work space. Because masonry surfaces can be more or less conductive under various circumstances, the code requires that concrete, brick or tile walls be considered as grounded. The NEC should be consulted for the minimum clear distances required for specific conditions involving exposed live parts on such equipment as switches, panelboards, circuit breakers and motor starters.

FLEXIBLE CORDS
Fixed Wiring Preferred

Because it can be designed for the particular type of service and location, fixed wiring is preferable to flexible cords, which can be misused and are more vulnerable to damage. Among wiring methods which can be used in certain circumstances are armored cable, rigid metal conduit, flexible metal conduit, raceways, nonmetallic sheathed cable and concealed knob-and-tube work. Which type is used will depend on several factors, including:

- the building materials themselves
- the size and distribution of the electrical load
- exposure to dampness
- exposure to corrosives (oil, grease, vapors, gases, fumes, liquids)
- exposure to temperature extremes
- the location of equipment.

Limitations of Permanent Wiring

Permanent wiring by itself cannot satisfy all the needs of the industrial/vocational education shop. Electrical cords and fittings provide the flexibility required for:

- maintenance
- portability
- isolation from vibration
- temporary power needs.

Therefore, the NEC recognizes electrical cords and fittings as a supplement to permanent installations. However, their selection, use and maintenance must be supervised carefully, and students must be warned that each use of a cord creates an additional hazard.

Classifications of Portable Cords

There are two general classifications of portable cords:

1. electrical cord sets with fittings used as extension cords. These have an attachment plug at one end and a cord connection with from one to six outlets at the other end.
2. power supply cords, either
    a. non-detachable—a flexible cord terminating at one end in an attachment plug cap and permanently attached at the other end to some utilization equipment (e.g., a hand-held power saw)
    b. detachable—a length of flexible cord with an attachment plug cap at one end and an appliance coupler at the other end (e.g., some portable drills).

Permitted Uses of Flexible Cord

NEC 400-7 specifies the situations in which flexible cord can be used. Those which might occur in the industrial/vocational education shop are:

1. electrical fixtures suspended from the ceiling
2. wiring of fixtures
3. connection of portable lamps and appliances
4. wiring of hoists and cranes

5. connection of stationary equipment to facilitate frequent interchange
6. facilitating the removal or disconnection of fixed or stationary appliances for maintenance or repair (e.g., water coolers, exhaust fans)
7. prevention of the transmission of noise or vibration.

In the last instance, it should be pointed out that vibration can so strain fixed wiring that a situation more hazardous than the use of flexible cord is created.

Prohibited Uses of Flexible Cord

The NEC (400-8) prohibits the use of flexible cords:

1. as a substitute for the fixed wiring of a structure
2. where run through holes in walls, ceilings or floors
3. where run through doorways, windows or similar openings
4. where attached to building surfaces
5. where concealed behind building walls, ceilings or floors.

Hazards of Temporary Wiring

The temptation in using temporary wiring is to allow it to become a permanent solution. Cord should not be extended to some distant outlet simply to avoid providing a needed fixed outlet. When new electrical needs are anticipated, time should be allowed for the proper installation of fixed wiring. When temporary wiring is necessary, a schedule for its removal should be established.

In all cases, both the number and length of extension cords should be kept to the minimum which is practical. Permanent receptacle outlets should be installed at convenient locations in order to limit the length of cord required for the job.

Extension cords should be listed by the Underwriters Laboratories, Inc. Receptacles and attachment plugs, which provide a connection for the equipment grounding conductor of the cord, should be listed for equipment grounding service by Underwriters Laboratories.

Cord that is used in ways prohibited by the code is likely to be damaged by abrasion from adjacent materials, edges or clamps.

Cord that is not visible for its entire length cannot be inspected for damage or deterioration. Over a period of time damaged cord will partially expose conductors, with the resulting dangers of shock, burns or fire.

Where cord use is permitted, the tripping and falling hazard it creates can be minimized by keeping the cord off the floor. An arrangement should be used that suspends the cord without abusing the cord materials. Special fittings for this purpose are available. Such an arrangement must be high enough to allow clearance beneath it.

When it is not practical to string cords overhead, a rubber treadle can be snapped over the cord. Molded in a light yellow color, the treadle protects the cord and minimizes the tripping hazard.

A cord should not be pulled or dragged over nails, hooks, tools or other sharp objects that can cut the insulation.

The NEC permits flexible cord only in continuous lengths without splice or tap. If the cord is damaged, the defective portion can be cut out and the remaining cord joined with the use of an additional attachment plug and conductor.

Special Hazards of Portable Hand Lamps

NEC regulations require that portable lamps be equipped with "a substantial guard attached to the lampholder or the handle" (410-42). Plastic or rubber insulated guards should be used:

1. where the guard might come in contact with an electrical circuit
2. where deteriorating agents such as oil and grease may be present in the work area.

Uninsulated guards should be electrically continuous with the equipment grounding conductor. Metallic guards must be grounded by means of "an equipment grounding conductor run with circuit conductors within the power supply cord" (410-42).

The NEC requires that portable lamps "be equipped with a handle of molded composition or other material approved for the purpose" (410-42). Handles should be made of a high-grade rubber compound or a similar material that gives maximum insulation and durability and resistance to oil and to softening at high temperatures. At the end where the cord enters the handle, there should be a dust seal. Where the flexible stem enters the base or stem of a portable lamp, a bushing or its equivalent must be provided. "The bushing shall be of insulating material unless a jacketed-type of cord is used" (410-44).

Metal shell, paper-lined lampholders are specifically prohibited by the NEC (410-42).

Portable Lamps in Auto Shops

Portable lamps used in locations similar to the auto shop are subject to special regulation. The NEC states that such lamps must be equipped with handle, lampholder, hood and substantial guard attached to the lampholder or handle. The regulation continues:

> All exterior surfaces which might come in contact with battery terminals, wiring terminal or other objects shall be of nonconducting material or shall be effectively protected with insulation. Lampholders shall be of unswitched type and shall not provide means for plug-in of attachment plugs. Outer shell shall be of molded composition or other material approved for the purpose. (511-2)

Choosing the Proper Cord[5]

The various types of cords apt to be used in an industrial/vocational education shop are listed in Table 23. The letter J in a

TABLE 23

TYPES OF FLEXIBLE CORD

Trade Name	Type Letter	Size AWG.	Number of Conductors	Insulation on Each Conductor	Outer Covering	Use		
Junior Hard Service Cord	SJ	18 to 14	2, 3, or 4	Rubber	Rubber	Pendant or Portable	Damp Places	Hard Usage
	SJO				Oil-Resistant Compound			
	SJT			Thermoplastic or Rubber	Thermoplastic			
	SJJO				Oil Resistant Thermoplastic			
Hard Service Cord	S	18 to 2	2 or More	Rubber	Rubber	Pendant or Portable	Damp Places	Extra Hard Usage
	SO				Oil-Resistant Compound			
	ST			Thermoplastic or Rubber	Thermoplastic			
	STO				Oil-Resistant Thermoplastic			

NOTE: Flexible cords and cables shall be marked by means of a printed tag attached to the coil reel or carton. The tag shall contain the information required in Section 310-11 (a) of the Code.

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designation stands for Junior. Residential-type cords are not designed to withstand the hard usage encountered in the shop; they should not be used.

Types S, SO, ST and STO cords are rated for extra hard usage. They have conductors that range in size from 18 to 2 AWG (American Wire Gauge) and are insulated with a material suitable for voltages up to 600 volts. Types SJ, SJO, SJT and SJJO are made only in conductor sizes 14, 16 and 18 AWG. They are rated for 300-volt insulation and are smaller than the extra hard usage types.

Both types depend upon the chemical composition of the jacket for the protection they provide against abrasion, water, oil, chemicals and temperature extremes.

The type of cord and plug required is related to the type and use of the equipment. A cord and plug adequate for a piece of equipment which is never moved may not meet the greater wear demands of a cord and plug used for portable tools.

The voltage impressed between the conductors or between conductor and ground should not exceed the voltage rating of the cord itself. Before the cord is put into use, the power supply voltage should be determined and checked against the rating of the cord.

The amperage required by the equipment that is to be connected to the cord can be determined from its nameplate. The voltage, frequency, current and phase characteristics of the circuit should match the nameplate characteristics of the fittings. The proper cord set can be selected by matching the nameplate information against the rating information on the cord set label or package. Units that draw large initial starting currents require cords of sufficient wire size to minimize the voltage drop which will be produced.

Unless the tool is double-insulated, extension cords must contain a separate equipment grounding conductor. Because the metal frames of portable electric equipment should be grounded, cord with a green-covered ground conductor should be used with a polarized plug and receptacle.

Sockets should be covered with porcelain, composition or rubber. Extension cords with brass shell sockets should not be used. The socket may become energized through contact with loose wires inside the socket, through abrasion of the insulation where the cord enters the socket or through moisture in the socket insulation.

Cord Maintenance and Storage

Before inspecting, repairing and servicing portable equipment and fittings, cords should be removed from the electrical power source. Electric cords and fittings should be inspected regularly. Cords should be wiped clean with a dilute detergent and examined for small breaks, abrasions and defects in the jacket. Fittings should be inspected for wear, looseness, arcing conditions or other mechanical defects.

Cord reels are recommended in locations where a power source or portable light is needed frequently. Reels pull the cord out of the way when not in use while still keeping it readily available for service.

Where reels are not used, cords should be coiled or hanked for storage. Care should be taken to avoid kinking or abrading the cord. Power supply cords should not be wound tightly around portable tools or hand lamps. This practice can damage the insulation and break conductor strands at the point where the cord is bent sharply.

PLUGS AND ATTACHMENTS

Plug and connector housings should be made of a material that will protect internal parts and connections from mechanical damage (see Table 24). For cords size 14 AWG or larger, heavy-

TABLE 24

Chemical Resistance of Materials Commonly Used in Writing Devices

Chemical	Nylon	Melamine	Phenolic	Urea	Polyvinyl Chloride	Polycarbonate	Rubber
Acids	C	B	B	B	A	A	B
Alcohol	A	A	A	A	A	A	B
Caustic bases	A	B	B	B	A	C	C
Gasoline	A	A	A	C	A	A	B
Grease	A	A	A	A	A	A	B
Kerosene	A	A	A	A	A	A	A
Oil	A	A	A	A	A	A	A
Solvents	A	A	A	A	C	C	C
Water	A	A	A	A	A	A	B

A—Completely resistant. Good to excellent for general use.
B—Resistant. Fair to good, limited service.
C—Slow attack. Not recommended for use.

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duty attachment plugs are recommended.

Nylon Housing Recommended

Nylon is the material recommended for standard use in the industrial/vocational education shop.[6] It is durable, an excellent insulator, and highly resistant to attack by chemicals. It is resilient enough to resist shattering when dropped or struck, yet hard enough to retain its shape even under great pressure. In the unlikely event that a nylon device is damaged, visual inspection easily reveals the damage. This is not true of rubber and neoprene devices, where the housing springs back into shape and conceals internal damage.

Preventing Tension on Terminal Connections

Cord terminations are far more vulnerable than those in fixed-wiring because such cord is exposed, flexible and in some cases not secured. The finely stranded wiring inside the cords is necessary for continuous flexing, but strands can escape from under terminal screws, creating a hazard.

Applicable Standard

According to NEC 400-10:

> Flexible cords shall be so connected to devices and to fittings that tension will not be transmitted to joints or terminal screws. This shall be accomplished by a knot in the cord, winding with tape, by a special fitting designed for that purpose, or by other approved means which will prevent a pull on the cord from being directly transmitted to joints or terminal screws.

All plugs that are attached to cords must have the terminal screw connections covered by suitable insulation.

Safe Practices

Students should be taught to disconnect a connection by pulling on the plug, not on the cord. A non-metallic cord gripper incorporated in plugs and connectors can prevent strain on the ground and power connections when someone pulls the plug out by the cord.

Locking-type attachment plugs, receptacles and connectors provide additional protection against accidental disengagement.

Before an attachment plug is inserted or withdrawn from a receptacle, the control switch on electrical equipment should be in the "off" position. This precaution prevents arcing at the plug.

Dead-Front Construction

Some plugs contain no screw heads on the front of the male plugs.

Isolated pockets are provided inside the body of the plug for each wire and its terminal.

This dead-front construction is preferable to merely securing mechanically the front covers for wire terminals. It eliminates the possibility of the common fiber disk cover coming off or allowing wire strands to protrude. It prevents the conductors from contacting a metal wall plate. It keeps out metal chips or other foreign substances which can enter when the disk is loose or improperly fitted.

GROUNDING OF CORD- AND PLUG-CONNECTED EQUIPMENT

Cord- and plug-connected equipment is subject to more abuse than equipment supplied by fixed wiring. If cord- and plug-connected equipment is not properly grounded, the voltage between the metallic parts and other surfaces in the vicinity may be sufficient to cause harmful or lethal shock. If a piece of conductive material becomes part of a ground-fault path, sparking and burning may result. Therefore, the grounding of such equipment, whether stationary or portable, is required by law for the safety of those exposed to it.

Additional Hazard Created by Current Leakage

A current leakage might be defined as an electrical current (generally less than one ampere) that has deviated from its normal path to ground (i.e., the neutral conductor) and is seeking an alternate route.[7] Such leakages are sometimes called "low current faults" and occur in all electrical equipment, even when it is new.

A good grounding system (e.g., the green wire, a rigid metal conduit) usually carries off this current leakage. Therefore, no shock is perceived when the current leakage of tools is below one ampere and the grounding current has a low resistance. Over a period of time, however, the dielectric properties of insulation wear down, and a greater amount of current can be measured on the metal frame or case of the equipment. Should the grounding conductor become inoperative (e.g., through a broken prong or increased resistance), the user of the equipment is placed in grave danger.

This hazard is far too frequent with portable and cord-connected tools and equipment, where loss of ground can occur without warning. Such equipment is sometimes used in damp or wet locations where good earth contact exists. Another hazard is created by the fact that portable and cord-connected tools usually require a full-hand grasp; in the event of insulation failure in the tool or wire, the student may not be able to release his grasp.

Applicable Standards

The NEC (250-45) specifies that "exposed noncurrent-carrying metal parts of cord- and plug-connected equipment likely to become energized" must be grounded in certain circumstances. These situations include several likely to occur in the industrial/vocational education shop. Specifically, the requirement applies to

1. such portable, hand-held, motor-operated tools as drills, sanders and saws
2. portable tools likely to be used in wet and conductive locations
3. equipment operated at more than 150 volts to ground (an exception is made for guarded motors)
4. hazardous locations, which include
    a. areas where flammable liquids and gases are used
    b. areas where combustible dust is present
    c. areas where materials producing easily ignitible fibers are handled or produced (e.g., woodworking).

Double insulated tools are exempted from the grounding requirement.

Typical Grounding System

The typical grounding system for cord- and plug-connected equipment consists of:

1. a third wire contained in the power cord
2. a three-prong plug with a grounding pin
3. a three-wire grounding type receptacle
4. a third or grounding conductor which connects the receptable grounding contact to the power distribution system ground (neutral) at the main service switchboard.

Three-Pronged Connectors

The basic safety feature on plugs is the three-pronged connection. Two prongs conduct electricity; the third goes to the ground. This system gives a continuous ground to the frame of the tool. A failure of insulation, which energizes the frame, causes a short through the equipment grounding conductor. This short actuates overcurrent protection devices such as fuses and circuit breakers.

This system provides excellent protection as long as the third-wire prong is kept intact and the grounding system from the outlet is unbroken. Students should be instructed never to use a plug with the third prong broken off.

Some attachment plugs are manufactured of high-impact transparent plastic material. Such plugs permit inspection of terminations without the necessity of disassembly.

GROUNDING

Purpose of Grounding

The purpose of the equipment grounding conductor system is to provide a low impedance (resistance) path to ground for currents resulting from faults or the inherent leakage of electrical apparatus. If the framework and cabinets of electrical equipment are purposely grounded, a path to ground for stray currents is provided before they reach and pass through a human body. The general rule for electrical safety is to *ground the equipment, but not the human body.*

Applicable Standards

The characteristics of an adequate grounding system are described in the following section (250-51) of the National Electrical Code:

> Effective Grounding Path. The path to ground from circuits, equipment, and conductor enclosures shall
>
> a. be permanent and continuous
>
> b. have capacity to conduct safely any fault current likely to be imposed on it
>
> c. have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices in the circuit.

Besides requiring the grounding of *equipment connected by cord and plug,* the NEC (250-42 and 43) requires the grounding of "exposed noncurrent-carrying metal parts of *fixed equipment* likely to become energized" under the following circumstances:

1. within eight feet vertically or five feet horizontally of ground or grounded metal objects
2. in a wet, damp, nonisolated location

8' = 2.4 m.
5' = 1.5 m.

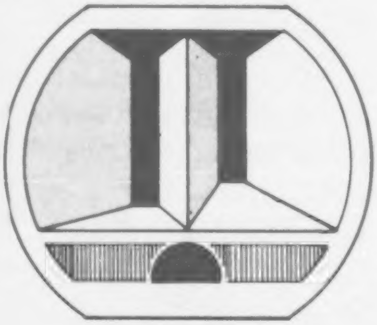
3. in electrical contact with metal
4. in a hazardous location
5. where supplied by a wiring method that is metal-clad, metal-sheathed or a metal raceway
6. where the equipment operates with any terminal in excess of 150 volts to ground.

The grounding of hoists and cranes is required by NEC 610-61

> All exposed metal parts of cranes, . . . hoists and accessories including pendant controls shall be metallically joined together into a continuous electrical conductor so that the entire crane or hoist will be grounded. . . . Moving parts, other than removable accessories or attachments having metal-to-metal bearing surfaces, shall be considered to be electrically connected to each other through the bearing surfaces for grounding purposes. The trolley frame and bridge frame shall be considered as electrically grounded through the bridge and trolley wheels and its respective tracks unless local conditions, such as paint or other insulating material, prevent reliable metal-to-metal contact. In this case a separate bonding conductor shall be provided.

Grounding Type Receptacles

In 1975 the NEC was revised to require the installation of only grounding type receptacles in new construction (210-7). A grounding type receptacle for 120V looks like this:



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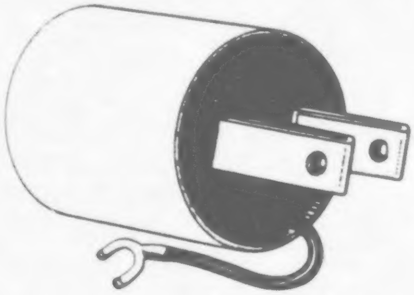
The right-hand (short) slot is the hot lead, the terminal from which the current flows. The left-hand (longer) slot is the grounded neutral connector, the terminal for the return path. The third slot (here pictured as semicircular) is for the grounding connector. In a 240V receptacle the grounding connector slot is shaped like the right- and left-hand slots.

Pigtail Connectors Not Allowed

A matching male connector with a fixed grounding prong is required for use with the receptacle. Pigtail connectors such as this are not among the accepted grounding connections:



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Pigtail connectors are not allowed by NEC 410-58 because they permit three conditions to exist:

1. The grounding wire may be left unconnected.
2. Even when the grounding wire is connected, it may be attached to an object that is itself ungrounded or is highly resistant to ground.
3. Electrocution can result if the pigtail grounding connector is accidentally inserted into the hot slot of the receptacle.

Non polarized standard plugs can be used in the receptacle.

Testing Receptacles

Over a period of time the ability of the grounding circuit in the receptacle to make contact with the plug grounding pin can be lost. To detect this condition requires determining the contact force or tension between the receptacle contact and the plug grounding pin. Such tests should be made by qualified persons, who are aware of electrical hazards and know how to avoid them. They should be scheduled on a regular basis. These inspections will enable the maintenance department to replace receptacles before they produce an ineffective equipment grounding contact or a fire develops in the power contacts.

PROTECTION AGAINST GROUND FAULTS

A ground fault occurs when some electricity, seeking to maintain continuity with the rest of the circuit, uses the ground as a conductor. If the body becomes part of the circuit, electrical shock can and does occur. If the ground contact is poor, the voltage will not be able to force a harmful current (amperage) through the resistance. But if the resistance is lowered through contact with grounded metal or damp concrete floors or through perspiring hands, the voltage will be able to force a larger current through the body.

A ground fault is thus distinguished from a short circuit, where two or more circuit conductors are crossed. However, this technical distinction is not always maintained in discussions of electrical safety.

Grounding protects against ground faults in equipment. These are usually caused by abrasion, aging or other damage which breaks through the insulation of conductors and allows the metal of the conductor to touch the enclosures or adjacent metal parts. An insulation breakdown can occur in the windings or other internal functioning parts of the equipment or in the wiring brought to or from the equipment.

Whenever a current-carrying conductor makes contact in this manner, the exposed metallic surfaces become energized at the same voltage as the conductor involved. The nature of voltage is that it will force current to flow

1. from one terminal of the source
2. out through the circuit conductor
3. through any available fault-current paths
4. back to the other source terminal.

If the metallic surfaces are not bonded together and to ground by a low-impedance equipment grounding conductor such as a conduit, dangerous voltage will exist

- probably—between electrical enclosures

- possibly—from some enclosures to plumbing, building steel and other grounded surfaces.

Because the fuse or circuit breaker will not open the circuit unless there is a large ground-fault current flow, the dangerous voltage may continue to exist.

Reversed Polarity

With the grounding-type receptacles and the matching male plugs, the condition known as "reversed polarity" is unlikely to occur. Reversed polarity means that, instead of coming into the equipment through the switch and exiting rhrough the neutral wire, the current exits through the hot wire. This means that the internal wiring is hot up to the switch, creating a shock hazard.

If a circuit tester indicates reversed polarity, the internal hot and neutral connections of the outlet should be interchanged immediately.

Every cord set and power supply cord should be checked for ground continuity and correct polarity before being placed in service.

OVERCURRENT DEVICES

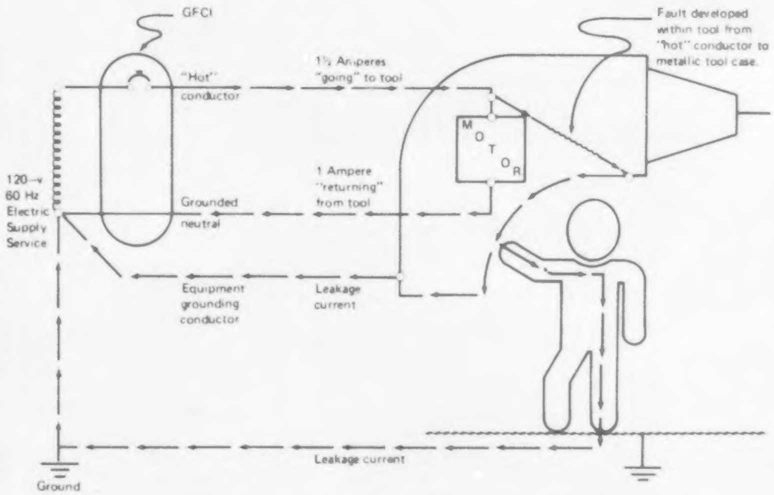
Overcurrent devices—such as fuses and circuit breakers—open the circuit automatically in case of excessive current flow from ground, short circuit or overload.

Ground Fault Circuit Interrupter (GFCI)

The ground fault circuit interrupter (GFCI) is a fast-acting circuit breaker which senses small imbalances in the circuit caused by current leakage to ground and, in a fraction of a second, shuts off the electricity. The GFCI continually matches the amount of current going to an electrical device against the amount of current returning from the device along the electrical path. Whenever the amount going differs from the amount returning by approximately two to five milliamperes, the GFCI interrupts the electric power within as little as 1/40 of a second (see Figure 63).

There are two types of ground fault circuit inte[illegible]pters:

1. *Differential*—Current carrying wires go through a differential transformer. If as little as five milliamperes do not flow through but trickle to the ground instead, the circuit breaker is tripped and the flow of electricity stopped.
2. *Isolation*—This type combines the safety of an isolation system with the response of an electronic sensing circuit. Ground fault passes through the electronic sensing circuit,


GFCI
"Hot" conductor
1½ Amperes "going" to tool
Fault developed within tool from "hot" conductor to metallic tool case.
MOTOR
120-v 60 Hz Electric Supply Service
1 Ampere "returning" from tool
Grounded neutral
Equipment grounding conductor
Leakage current
Leakage current
Ground

GROUND—FAULT CIRCUIT INTERRUPTER

GFCI monitors the difference in current flowing into the "hot" and out to the grounded neutral conductors. The difference (1/2 ampere in this case) will flow back through any available path, such as the equipment grounding conductor, and through a person holding the tool, if the person is in contact with a grounded object.

Reprinted from *Ground-Fault Protection on Construction Sites,* U.S. Department of Labor, Occupational Safety and Health Administration, Bulletin 3007 (1977), p. i.

Figure 63

which has enough resistance to limit current flow to as little as two milliamperes.

The GFCI can operate on both two-wire and three-wire (equipment grounding) systems. It protects both two-wire and three-wire equipment and monitors the system continuously.

According to the National Safety Council, there has not been a single recorded electrocution from ground fault in any installation employing a GFCI.[8] The ground fault circuit interrupter also provides protection against fires, overheating and destruction of insulation on wiring.

A GFCI does not protect a person from line-to-line hazards, such as those developing when a person is holding two hot wires or a hot and neutral wire. It is no substitute for good electrical safety procedures.

In the industrial/vocational education shop GFCIs should be used

1. where water and electricity are used in close proximity (e.g., where motors or other electrical apparatus are located near sinks and basins
2. where the user of electrical equipment cannot avoid being grounded
3. on circuits providing power to portable tools and to outdoor receptacles.

Portable models are available.

Fire Hazards Created by Overloading

Electrical conductors and machinery are designed to carry a rated load. Their safe current-carrying capacity is determined by their size, the material of which they are made, the type of insulated covering and the manner of installation. If they are forced to carry loads greater than their capacity, the result is overheating.

For example, if a 1/4 horsepower motor is given a load of one horsepower, it will try to carry that load but probably will burn itself up in the process. Because the voltage is constant, the motor will draw more current. The excess current will heat the electrical conductors to the point where they will break, creating a fire hazard. Such overheating frequently causes the insulation to burn, exposing live parts. Fires sometimes start because electrical conductors within a wall raise a combustible material to its ignition temperature, causing it to burn.

Overcurrent Devices

Overcurrent devices open the circuit automatically when triggered by

1. excessive current flow from
   a. overload
   b. accidental ground
   c. short circuits
2. circuit interrupter causing a circuit breaker to open.

Overcurrent devices are basically passive. They operate only when something goes wrong. They do not substitute for ground fault circuit interruptors but supplement them.

Fuses and circuit breakers operate on a time-versus-current principle. The larger the amount of current, the shorter the time required to break the circuit. So that large amounts of current can flow quickly, activating overcurrent devices and protecting the circuit from damage, it is important for the grounding conductor to:

1. be continuous
2. have low impedance
3. have sufficient ampacity.

Fuses

A fuse is a part of a conductor in a circuit. When too much current flows through, the fuse heats up within a fraction of a second. The fusible metal melts and interrupts the circuit.

There are three kinds of fuses:

1. link fuse—a fusible metal forms a strip between the two terminals of a fuse block
2. plug fuse—used on circuits which do not exceed 30 amperes at not more than 150 volts to ground, the fusible metal is completely enclosed
3. cartridge fuses—the fusible metal strip is enclosed in a tube.

Maintaining Fuses

Each type should be used only in the circuit for which it was designed. Fuses of the wrong type or size can injure personnel and damage equipment.

Fuses never should be inserted in a live circuit. When it is necessary to remove a fuse, the circuit should be locked out. The fuse should be extracted with an insulated fuse puller. If the fuse is not protected by a switch, the supply end should be pulled out first. When the fuse is replaced, the supply end should be put in first.

A copper wire or other conductor must never be substituted for a fuse. A larger fuse never should be used to replace a blown fuse. Overfusing can cause overheated wiring and equipment, creating the very fire hazard that fuses are designed to prevent.

Circuit Breakers

A circuit breaker is a switch so placed in a circuit that it opens automatically if a certain temperature is reached or if too much current flows through the switch. A circuit breaker may operate instantly or be equipped with a timing device.

There are two general types:

1. thermal, operating only on the basis of temperature rise
2. magnetic, operating only on the basis of the amount of current passing through the circuit.

Applicable Standards

The NEC (430-32) requires that all circuits be equipped with fuses or circuit breakers that will open if the actual current flow in a circuit exceeds the expected flow by 25 percent. For example, if a circuit is normally expected to carry a load of sixteen amperes, the fuse or circuit breaker must be rated at twenty amperes. The NEC further requires that the conductors in the circuit be able to carry the 25 percent excess load without overheating.

For welders, the NEC (630-12, 630-22, 630-32) requires overcurrent protection set at not more than 200 percent (for arc welders) or 300 percent (for resistance welders) of the rated primary current of the welder.

Locating Overcurrent Devices

According to NEC 240-24, overcurrent devices must be located where they are:

1. readily accessible, which is defined in NEC 100 as "capable of being reached quickly for operation, renewal or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc."
2. not exposed to physical damage
3. not in the vicinity of easily ignitible material.

Overcurrent devices frequently serve as disconnecting means. Therefore, they must be readily accessible when troubles occur. Furthermore, devices which are difficult to reach are apt to be neglected. In the case of overcurrent devices, neglect can lead to overheating and fires.

DETECTING OVERLOADS

Supervisors and instructors in school shops must make certain that circuits are not overloaded. Even if overcurrent protection devices function properly and prevent fire or heat hazards, there is still the inconvenience of resetting the breaker or replacing the fuse.

Signs of Overloading

What are some signs of overloading?

1. The fuse or circuit breaker frequently opens the circuit. If this happens, try to determine if a certain machine when it is energized is causing the interruption.
2. A ground fault circuit interrupter interrupts the circuit frequently.
3. An electrical machine feels abnormally hot.
4. An extension cord becomes warm.
5. A cable bank, fuse box or junction box feels abnormally warm.
6. The insulation of conductor is worn or frayed.

If any of these conditions exist, a maintenance electrician should be called.

Investigating Overloads

Before fuses are replaced or circuit breakers reset, an investigation should be made for the cause of the short circuit or overload. To ignore the warning signals which have been built into the system is foolish and shortsighted.

MAINTAINING PROTECTIVE DEVICES

According to one researcher, the cost of the electrical system in any facility is only 7-1/2 percent of the total cost even though the facility is useless without electric power.[9] Saving a few cents by cutting corners on maintenance is false economy. It undercuts the sound investment that has been made in designing and installing a safe system.

We have seen how electrical protective devices are the safety valves of the system. Overcurrent protective equipment must be checked periodically to be certain that it works properly when troubles occur. The maintenance needs involve five steps:

1. clean
2. tighten
3. lubricate

4. inspect
5. test.

Clean

Fuses, relays and circuit breakers must be cleaned periodically to eliminate dirt, dust, moisture and contaminants which can make the system ineffective.

Tighten

All electrical connections must be tight. A loose connection generates excess heat, which can erode metal.

Lubricate

Lubrication is necessary to keep the mechanical joints or sliding parts in circuit breakers from becoming rusty over a period of time. Such lubrication must be done carefully so that improper lubricants are kept away from electrical contacts.

Inspect

All electrical protective devices need to be checked to be certain that their interrupting rating and their setting is in accordance with the design. Such inspection will detect instances where the capacity of the device has been increased to keep the circuit from tripping. For example, if a 15-ampere circuit breaker or fuse has been replaced by a 20- or 25-ampere device, an accident is just waiting to happen.

Test

If it has a built-in test feature, the circuit breaker, fuse or relay can be subjected to simulated fault conditions to make sure that it operates in accordance with the manufacturer's specifications for the device being tested.

Such a maintenance program as the one described will ensure that devices have not been impaired by

- dusty, oily, smoky or corrosive atmospheres
- mechanical vibration
- excessive temperature
- tampering.

IDENTIFYING DISCONNECTING MEANS

The electrical system for an industrial/vocational education shop originates at a service entrance, from which feeders carry current to branch circuits. These in turn carry current to the outlets for lighting, machinery and equipment. It is important to identify the switches and circuit breakers which control the power to each particular circuit.

Applicable Standard

According to the NEC (110-22):

> Each disconnecting means required by this Code for motors and appliances, and each service, feeder or branch circuit at the point where it originates shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. The marking shall be of sufficient durability to withstand the environment involved.

When Disconnection is Necessary

During the life of any electrical installation, there will be times when it is necessary to disconnect a branch circuit, a feeder or an entire service. The reason may be:

1. normal maintenance procedures, whether scheduled or unscheduled
2. changes or additions to the system
3. emergencies requiring quick action to disconnect power from a particular piece of equipment or portion of the system
4. major emergencies such as fire or explosion, which require that all power in the building be turned off quickly.

If the appropriate disconnecting means is not obvious, mistakes may be made or vital time may be lost in tracing circuits to their source. If the circuit conductors, or the raceway containing them, are visible from the disconnecting means to the equipment involved, the purpose may be evident. However, a sign, label, tag or nameplate on the disconnect is necessary in most cases to meet the needs of quick identification.

Instructor Involvement

In many schools there is one person who knows the electrical system like the back of his hand. Usually this is the person responsible for maintaining electrical circuits and equipment. It is easy for the industrial/vocational education instructor to assume that this key person always will be available to identify disconnecting means.

But emergencies can and do occur when there is no time to consult the specialist. Harmful shocks and even electrocutions can result from the wrong switch being opened or closed in a panic situation. Fires can start if a faulted circuit is not disconnected quickly enough. Therefore, the instructor must insist that switchboards and control panels are adequately identified.

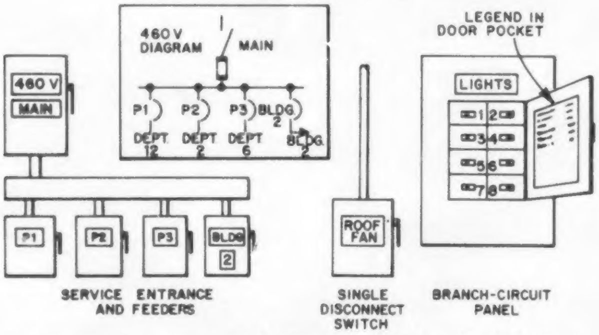
Steps in Identifying Disconnecting Means

Where there is inadequate identification, not only is the school violating the National Electrical Code but also a known hazard is being allowed to exist. The instructor will want to urge that the following steps be taken immediately, with the supervision of the Safety and Health Committee:

1. Trace out all existing circuits, from service entrance to utilization equipment, and clearly mark each disconnecting device to indicate what circuit or what equipment it disconnects.
2. Make sure that exceptions to the above are permitted only where the circuit conductors or their raceway are clearly visible from the disconnecting means to the load.
3. Use labels or nameplates which are permanently legible.
4. Do not depend entirely on anyone's memory to identify circuits for proper labeling.
5. When numbers or letters are used to identify circuits and equipment, be sure that the system layout or key diagram is posted so that the key can be interpreted and the circuit located.

Figure 64 illustrates some forms of proper identification, which can save both lives and equipment.

LABELING DISCONNECTING MEANS


460 V
MAIN
460 V DIAGRAM
MAIN
P1
P2
P3
BLDG 2
DEPT 12
DEPT 2
DEPT 6
BLDG 2
P1
P2
P3
BLDG 2
ROOF FAN
LEGEND IN DOOR POCKET
LIGHTS
1
2
3
4
5
6
7
8
SERVICE ENTRANCE AND FEEDERS
SINGLE DISCONNECT SWITCH
BRANCH-CIRCUIT PANEL

Reprinted from "Electrical Hazards, OSHA and the National Electrical Code," Part IV, by William S. Watkins and Associates, Inc., Willoughby, Ohio. No date given.

Figure 64

MARKING ELECTRICAL EQUIPMENT

Besides identifying the purpose of a disconnecting means, the NEC requires that equipment be marked with its appropriate ratings so that it can perform its function as intended. Observing the limiting conditions will prevent the operator from subjecting the equipment to conditions which will damage it and possibly cause injuries.

Applicable Standards

According to NEC 110-21:

> The manufacturer's name, trademark or other descriptive marking by which the organization responsible for the product may be identified shall be placed on all electric equipment. Other markings shall be provided giving voltage, current, wattage or other ratings. . . . The marking shall be of sufficient durability to withstand the environment involved.

A metalworking machine must have attached either to the control equipment enclosure or to the machine itself where plainly visible after installation "a permanent nameplate listing supply voltage, phase, frequency, full-load currents, ampere rating of largest motor, short-circuit interrupting capacity of the machine overcurrent protective device if furnished, and diagram number" (670-3). When the machine tool nameplate is marked "overcurrent protection provided at machine supply terminals," each set of supply conductors terminates in a single circuit breaker or set of fuses.

For AC transformer and DC rectifier arc welders, the nameplate must include "name of manufacturer; frequency; number of phases; primary voltage; rated primary current; maximum open-circuit voltage; rated secondary current; basis of rating, such as the duty-cycle or time rating" (630-14).

If equipment is connected to a voltage higher than its rating, violent failure may result. If the voltage is below its rating, the equipment may overheat and eventually fail. If alternating current equipment is energized with the wrong frequency or with direct current, violent failure may result. Any of these abuses can lead to burns and fires.

Use of the Nameplate

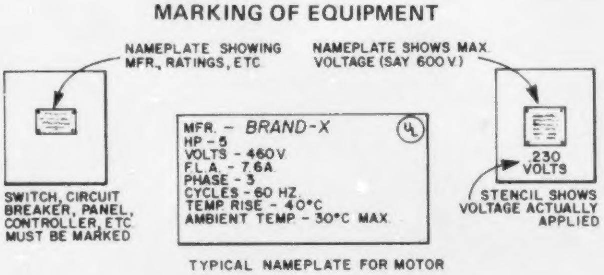
The instructor and supervisor must be certain that the nameplate on a machine or tool is not removed, covered by some part of the installation or obliterated by painting or other abuse.

When a nameplate gives an alternate or a maximum rating for the equipment, a specific marking should be added to the machine to indicate what voltage is actually being applied. For example, some machines can operate on either 115 or 230 volts, depending on internal conditions. The nameplate will not indicate which of these is the applied voltage so a supplementary marking (stencil, decal, etc.) is necessary.

The manufacturer's name on the nameplate is useful if information needs to be sought or if replacement parts need to be ordered. The symbol or notice of testing or listing (e.g., "U.L.") is useful for an inspector.

The industrial/vocational education instructor and supervisor will want to be certain that the proper electrical characteristics for the particular shop will be specified when new equipment is bought.

Figure 65 indicates examples of proper equipment marking.


MARKING OF EQUIPMENT
NAMEPLATE SHOWING MFR., RATINGS, ETC
NAMEPLATE SHOWS MAX. VOLTAGE (SAY 600 V.)
MFR. – BRAND-X
HP – 5
VOLTS – 460V
F.L.A. – 7.6A
PHASE – 3
CYCLES – 60 HZ.
TEMP. RISE – 40°C
AMBIENT TEMP. – 30°C MAX.
UL
230 VOLTS
SWITCH, CIRCUIT BREAKER, PANEL, CONTROLLER, ETC. MUST BE MARKED
STENCIL SHOWS VOLTAGE ACTUALLY APPLIED
TYPICAL NAMEPLATE FOR MOTOR

Reprinted from "Electrical Hazards, OSHA and the National Electrical Code," Part IV, by William S. Watkins and Associates, Inc., Willoughby, Ohio. No date given.

Figure 65

SPECIAL NEC PROVISIONS

In this unit specific wiring requirements have not been dealt with in detail. When the school was constructed, inspectors would have checked to see that wiring was installed in accordance with the National Electrical Code.

However, other requirements of the code relate more to operation than to installation. They have been cited throughout the unit. In this section we will examine specific regulations for hazardous areas, especially the auto shop.

Hazardous Areas

The industrial/vocational education shop contains hazardous areas, places where flammable liquids and gases are stored and used (e.g., auto shop, paint spraying). The NEC requires (511-6, 516-7) that equipment which can produce "arcs, sparks or particles of hot metal" be either totally enclosed or so constructed that sparks and hot metal particles cannot escape. Included in this description are cutouts, switches, receptacles, charging panels, generators, motors or "other equipment having make-and-break or sliding contacts."

Auto Shop

Special wiring is required in the auto shop because it is a hazardous location, containing vehicles which use volatile flammable liquids and gases for power and fuel. NEC 511 gives specific information.

The flexible cord by which electrical fixtures are suspended from the ceiling must be suitable for the type of service and approved for hard usage. Only flexible cord and connectors approved for extra-hard usage may be used for charging.

Connectors used for charging must be so "designed and installed that they will disconnect readily at any position of the charging cable" (511-8). When a cord is suspended from overhead in order to connect a plug directly to the vehicle, it must be so arranged that the lowest point of sag is at least six inches above the floor.

6" = 15 cm.

Racks used for supporting battery cells and trays should be made of metal and treated to resist deteriorating action by the electrolyte. They must be "provided with nonconducting members directly supporting the cells or with suitable insulating material other than paint or conducting members" (480-7). Trays may be of wood or other nonconductive material treated to resist deterioration.

WHAT THE STUDENT NEEDS TO KNOW

In this unit we have discussed electrical safety in the shop, what aspects need to be considered in installing and maintaining the electrical system and what practices need to be part of the day-to-day operation. Throughout the unit, the emphases have been on acquainting the instructor with existing or probable electrical hazards and giving him the information he needs to ensure electrical safety in the school shop.

At this point, the instructor may ask, "But what do my *students* need to know about electrical safety?" The following are points which the instructor will want to transmit to his students. This list is not exhaustive and may be modified to suit the needs of the particular shop situation.

Insulation

1. Keep tools and cords away from heat, oil and sharp edges that can damage electrical insulation.

Plugs

2. Disconnect tools and extension cords by holding the plug, not by pulling on the cord. Be sure that the control switch on electrical equipment is in the "off" position before putting in a plug or pulling it out.

Three-Prong Plugs

3. Never use a three-prong grounded plug with the third prong broken off. Always plug in three-prong plug into a properly installed three-prong socket.

Damp or Wet Areas

4. Do not use electrical equipment in damp or wet areas.

Metal Ladders

5. Do not use electrical equipment on or near metal ladders, which conduct electricity.

Tools Running Hot

6. If tools or cords run very hot, report the condition to the instructor. The insulation could be deteriorating. Never wrap a cloth around a tool too hot to hold. Sparks can ignite the cloth.

Damaged Tools or Equipment

7. Report immediately any damaged tool or equipment or one that gives off minor shocks. Report any exposed live parts immediately. Do not attempt to make repairs yourself.

Extension Cords

8. Avoid using extension cords. When an extension cord must be used, choose one with the same ampere rating as the tool. Make sure that the insulation is intact and that all connections are tight. Make sure that the cord does not create a tripping hazard.

GFCIs

9. Use a Ground Fault Circuit Interrupter when using portable tools.

Overloaded Circuits

10. Do not overload circuits.

CONCLUSION

Electricity is essential to everyday shop operations. When safety is viewed as an important component of the total shop program, then the benefits of electricity can be enjoyed while its dangers can be recognized and controlled.

NOTES

1. *Accident Facts 1978* (Chicago: National Safety Council, 1978), p. 12.

2. C. C. Kleronomos, "Electrical Hazard Detection and OSH Act Compliance," *National Safety News* (September 1976), p. 68.

3. See Ralph H. Lee, "Electrical Safety in Industrial Plants," *ASSE Journal* (September 1973), p. 36.

4. *Ibid.*

5. Material in this section is adapted from "Electrical Cord and Fittings," National Safety Council Data Sheet, I-385-79, as published in the *National Safety News* (May 1979), pp. 75—80.

6. See Norman C. Johnson, "Better Wiring Devices Improve Safety," *National Safety News* (May 1974), pp. 72—75.

7. This is the definition used by Kleronomos in the article cited in Note 2 (p. 70).

8. See "Ground Fault Circuit Interrupters for Personnel Protection," National Safety Council Data Sheet 636, *National Safety News* (February 1973), p. 81.

9. Henry S. Orth, "Are You Protected?" *National Safety News* (May 1974), p. 68. Material in this section is adapted from this source.

QUESTIONS AND ANSWERS

1. What is the NEC, and why is it important?

The National Electrical Code contains the universally accepted minimal requirements published mutually by the National Fire Protection Association and the American National Standards Institute. All electrical installations are supposed to comply with the requirements of the code.

2. Define electrical current, and state in what units it is measured.

Current is the rate at which electricity flows through a circuit. It is measured in amperes.

3. Give two reasons why lower voltages are dangerous.

a. The victim may be "frozen" to the circuit, unable to let go of an object held in the hand.

b. The victim may lose his balance and fall because of mild shocks.

4. Name three variables which determine the severity of shock.

Any three from among the following:

a. voltage, how much electricity is involved

b. resistance, how many ohms impede the flow of voltage

c. duration of current flow

d. frequency of electrical waves (in an alternating current)

e. the part of the body exposed.

5. Briefly state the object of electrical safety.

The object of electrical safety is to prevent the human body from becoming part of the conductive path.

6. What are four kinds of protection to prevent current from flowing through the human body?

a. isolation

b. insulation

c. grounding

d. overcurrent protection

7. Why is fixed wiring preferable to flexible cords?

Flexible cords are more likely to be damaged or misused.

8. How can students prevent tension on the terminal connections of a cord?

Students can disconnect the cord by pulling the plug, not on the cord.

9. Why should students never use a plug with the third prong broken off?

The grounding system is no longer operating.

10. True or False — If a three-prong plug is not available for use in a grounding receptacle, a pigtail connector should be used.

False. Pigtail connectors are not allowed by the revised National Electrical Code.

11. What is a GFCI? Name two places in the shop where it should be used.

A ground fault circuit interrupter (GFCI) is a fast-acting circuit breaker which senses small imbalances in the circuit caused by current leakage to ground and, in a fraction of a second, shuts off the electricity. In the shop, it should be used (any two of the following):

a. where water and electricity are used in close proximity (e.g., where motors or other electrical apparatus are located near sinks and basins)

b. where the user of electrical equipment cannot avoid being grounded

c. on circuits providing power to portable tools

d. on circuits providing power to outdoor receptacles.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1981—757-074/1088